Impact of Ministry Schools' Envelopes on Daylighting and Energy Performance in the UAE

تأثير أغلفة المدارس الوزاريــة على أداء ضـوء النــهار والطــاقة في دولـة الإمـارات العربية المتحدة

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Abstract

Students spend most of their time at schools in one space where it should be well lit and ventilated during the school day. Integrating daylighting within a school building is an important factor for a vital sustainable design. Daylighting is not only by adding windows, but it's also by letting a good amount of daylighting into the classroom, putting into account to control the undesired sunshine radiations, it's also responsible for increasing students' attendance and improving their performance in a healthy IEQ. Many guidelines can be derived and established with reference to Practical experiences conducted by professionals in design and construction fields. This research is concerned with evaluating the school building envelope and its impact on the daylighting uniformity and sufficiency in the classrooms, and the possibility of saving electrical lights and cooling loads that can be reduced by the help of design elements such as glazing size and shape, building construction materials, proportions and ratios of various elements of the classroom. The motivation in this research is to assess classrooms of the dominant types of ministry schools in the UAE; to discuss the existing situation, then to implement potential solutions that can adjust the school to be a better space. Computer simulation was chosen as a method to conduct this research and analyze all models. All strategies were modeled and evaluated using IES-VE 2015 programme where parameters, configurations, models simulations and outcomes showed daylighting, artificial lights and electrical loads of 24 scenarios, then comparisons were tabulated in charts with respect to each of the additional 21 proposed aspects. A final scenario was created using the best results of each of the variable aspects evaluated before; to estimate the possibility of achieving an optimum case that has the best saving and performing characteristics with regards to the attracted research criteria.

ملخص

يقضي الطلاب معظم وقتهم في مكان واحد في المدارس حيث يجب أن تكون جيدة الإضاءة و التهوية خلال اليوم الدراسي. دمج ضوء النهار داخل المبنى المدرسي هو عامل مهم لتصميم حيوي و مستدام. ضوء النهار هو ليس فقط عن طريق إضافة نوافذ، و لكنه أيضا يتم بنجاح عن طريق السماح لكمية لا بأس بها من ضوء النهار في الفصول الدراسية، و يجب أن نضع في عين الاعتبار السيطرة على إشعاعات الشمس الغير مرغوب فيها، كما انها مسؤولة عن زيادة حضور و تواجد الطلاب وتحسين أدائهم في أجواء داخلية صحية (IEQ). العديد من المبادئ و الإرشادات يمكن أن تستمد بالرجوع إلى التجارب العملية التي أجريت من قبل المتخصصين في مجالات التصميم و البناء. تعتبر الإضاءة من أهم العوامل المؤثرة على فعالية الفصل الدراسي وتؤثر كميات النور والوهج بشكل مباشر بحجم وارتفاع واتجاه النوافذ. و أضف على ذلك عمق الفصل الدراسي والمواد المستخدمة في السقف والأرضيات وعلى الجدران هي أيضا من العوامل المؤثرة بشكل واضح على توزيع اللإنارة في الحيز.

هذا البحث مهتم بتقييم غلاف المبنى المدرسي وأثره على توحيد ضوء النهار والاكتفاء في الفصول الدراسية، ودراسة إمكانية توفير أحمال المصابيح الكهربائية و التكييف التي يمكن أن تنخفض بمساعدة عناصر التصميم من مثل حجم وشكل فتحات الزجاج، مواد البناء، تانسب والتناسب (Ratios) فيما يخص عناصر مختلفة للفصول الدراسية. الدافع في هذا البحث هو تقييم الفصول الدراسية ذات النوع السائد في مدارس الوزارة لدولة الإمارات العربية المتحدة، و ذلك لمناقشة الوضع الحالي القائم، ثم لتنفيذ الحلول المحتملة التي يمكن أن تعالج المدرسة لتصبح أفضل من حيث المساحة و الأجـواء الداخلية . وقد تم اختيار محاكاة الكمبيوتر كوسيلة لإجراء هذا البحث وتحليل جميع الموديلات. وعلى غرار جميع الاستراتيجيات فقد تم تقييمها باستخدام IES-VE برنامج 2015 حيث أظهرت معاملات التغيير في التجارب، الترتيبات و التحضيرات لنماذج المحاكاة، وقامت النتائج بإظهار ضوء النهار والإضاءة الاصطناعية والأحمال الكهربائية لكل من (24) سيناريو، ثم تم جدولة مقارنات على شكل الرسوم البيانية و تم ربط تلك المقارنات مع النماذج ال21 الإضافية المختلفة الجوانب. تم إنشاء سيناريو نهائي باستخدام أفضل النتائج من كل من الجوانب المتغيرة التي تم تقييمها من قبل؛ لتقدير إمكانية تحقيق حالة مثلى لديها خصائص مميزة و أفضل قدرة على الترشيد عن طريق طرح حلول معمارية مستوحاة من الاستدامة للحصول على فصل دراسي ممتع و مريح أكثر مع كميات كافية من النور الطبيعي.

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Abbreviations

CFD	Computational Fluid Dynamics
DF	Daylight factor
DM	Dubai municipality
IEQ	Indoor Environment Quality
IES	Integrated Environmental Solutions
LCP	Laser Cut Panels
LEED	Leadership in Energy and Environment Deign
MOE	Ministry Of Education
MOPW	Ministry Of Public Works
NCM	National Calculation Methodology
PBRS	Pearl Building Rating System
RD	Room Depth
VNLS	Virtual Natural Lighting Solution
WHDR	Wall Height to Depth Ratio
WHWR	Window Height to Width Ratio
WWR	Window to Wall Ratio

CHAPTER 1

INTRODUCTION

1.0 Introduction

1.1 Background information

Educational has always been an ambitious step and a top priority for the human being to be advanced in different fields that concerns our life. Lately, it became a crucial role to decide the students' outcomes, and parents turned more conscious about choosing the best quality of school where their kids will commit to spend most of their time on the daily bases. The building envelope, natural lighting presence, colors and facilities at school are important factors to distinguish between the schools in terms of their Indoor Environment Quality (IEQ) and students comfort and satisfaction. IEQ comprises of temperature condition, illuminance and levels of sound as Ghita and Catalina (2015) mentioned and highlighted the importance of each parameter that designers should deal with. Fadeyi et al. (2014) stated that space and thermal conditions, indoor air, sound levels and visual factors are elements of IEQ that should be compromised to effect positively on students and teachers' health and levels of comfort. Much collaboration should be done between the community and the architects and designers to understand the real needs in buildings and fulfill their desires.

Many famous architects expressed interests in combining their buildings within natural lighting, and that was significantly clear with the famous architect Le Corbusier who created his architecture with respect to many natural factors which effect on the building relation with the site context. People are experiencing a unique feeling in Notre Dame du Haut where the deep colored windows let the daylight into the space to create a serene spirit. Louis Kahn, Frank Lloyd Wright, Richard Meier, Tadao Ando, Jean Nouvel are icons of architecture –in addition to plenty of the present modern architects- who integrated natural daylighting in their architecture like in some pieces of art such as the Kimbell Art Museum, Johnson Wax Building, Smith House, and Institut Du Monde Arabe. Louis Kahn emphasized that a room which does not have natural light cannot be considered as a proper space, and even designing a structure should relate to lighting characteristics. Adding natural lighting as an element of design is fundamental and making an envelope that receives a sufficient daylighting will keep the building healthy and relaxed (Barrett, 2009).

1.2 Design elements

Daylighting has always been a vital element that can improve the quality of life on earth where the sun is only source of light that provides both heat and lighting for humans. We need lighting as we have many activities to do within our range of time along the day and night. Our consumption is increasing gradually with the growing populations and the continuous need for more buildings. Freewan (2010) mentioned that there is a great quantity of energy for lighting is consumed in buildings, and that will increase the amounts of CO2 accordingly causing hazardous environmental impacts.

Designers aim to implement an energy efficient building which has the optimum human comfort and sustainable performance with the best visual comfort adapted according to the recommended guidelines in professional practices whether for natural or artificial lights. It's vital to note that florescent light has stability and uniformity characteristics to add in the space. Artificial light was invented in 1930s which lately endorsed architects to design some spaces without openings for higher flexibility in the space (Barrett, 2009). Combination between natural and artificial lighting is important to achieve the visual needs in some design cases where some plans should be in a certain criterion of depth.

There are means of design which influence architects to decide the best building elements and envelope layout. Orientation of the building, position, building materials, building envelope, glazing ratios, internal space ratios and layout are important factors that effect on the ecology of the building and its performance.

1.3 Benefits of daylighting

There is no coincidence that designing buildings aim to harvest daylighting as an advantage in the internal space and it helps in improving IEQ in the desired rooms. There are many ways to gather daylighting but mainly from windows, skylights and solar-tubes. Daylighting is initially a free source and energy saver element where there is a good amount of reduction in electricity due to less artificial light use. Many studies were conducted to find and investigate the relationship between daylighting presence and the performance of users at schools.

Leslie, Radetsky and Smith (2011) recommended to include daylight as a basic element in design phase and should be formulated according to the required quality, views, proposed cost and the quantity of prototypes. They argued that daylighting has an impact on human well-being and health. It's also a sustainable approach to have daylighting in design stages, and it's a better economical way of thinking to reduce amounts of energy required to light, heat or cool the space.

Parise and Martirano (2013) described that lighting system one of the major items to be considered while designing, and if the daylighting is well used it can illuminate the required spaces and that will decrease the electric lighting needed in the space during the whole life of that building. Efficiency of the rooms should be as a result of a proper study to get the best results and performance of the building, especially in some interior zones where no natural lighting accessibility. Haqparast and Ahmadkhani Maleki (2014) mentioned that there are many benefits of daylighting which should be applied in all buildings types as shown in figure (1.1), even if designer are relying lately on the artificial lighting to insure the needed sufficiency in the space. Daylighting helps increasing productivity of the users, and better health and comfort for the occupants. Also, it can reduce the amounts of cooling required in the building in the short and long terms.

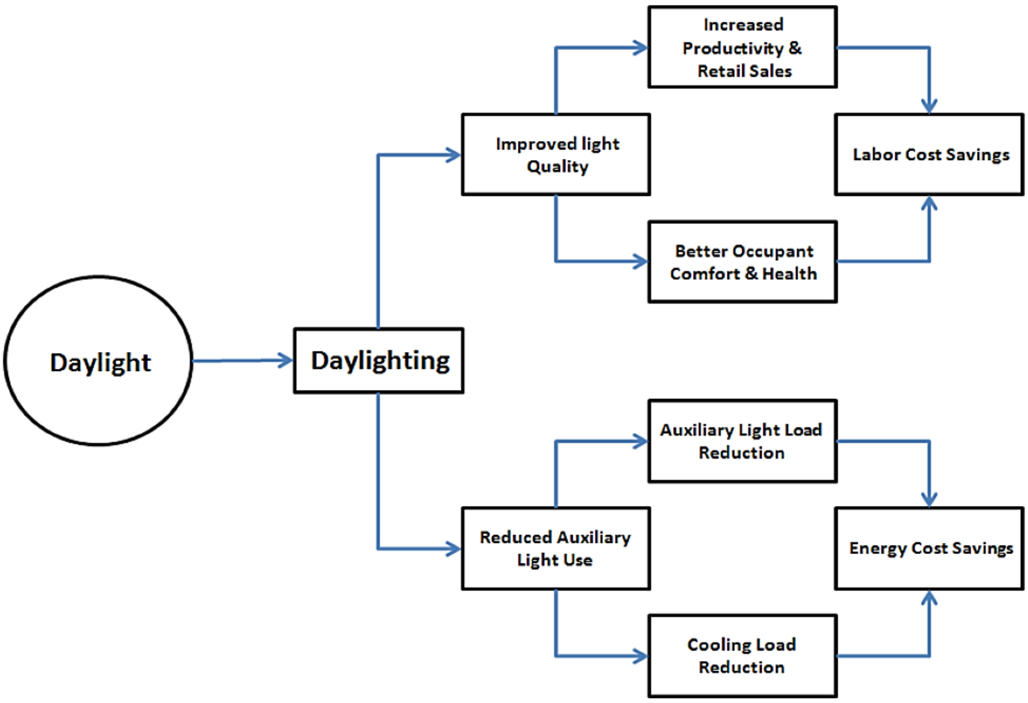


Figure (1.1) Benefits of using daylighting (Haqparast and Ahmadkhani Maleki, 2014)

Thompson, Donn and Osborne (2011) mentioned that daylighting has a great impact on health as well as the end-user productivity. They mentioned that heating the space and saving energy can be obtained by designing a proper building that studies daylighting and evaluates the operation of envelopes to get the most possible dynamic building performance. Wang and Boubekri (2010) established that daylighting has psychological and physical -or physiological- benefits. And that was illustrated more in depth in many studies which were concerned about the buildings and their need and benefit of natural lighting like schools, hospitals, shops, and office buildings. They clarified that achieving a healthy IEQ is not only by providing a daylight in the building, but a further step is needed which interacts with the personal use of the space, and what they can feel about the amount of that natural incident daylighting. The Illuminating Engineering Society of North America (IESNA) is involved in daylighting, and they recommended evaluating the space with the absence of occupants; to obtain neutral results for the designed room.

Leadership in Energy and Environmental Design-New Construction (LEED-ND) also provided a standard that is concerned about energy and potentials to save it through materials properties and U values. For instance, they require a minimum of 2% for DF, or not less than 25 foot candles (fc) -which is equal to 269 lux- in 3/4 of the occupied space. While there is an international Council for Codes, it highlighted that a minimum of 8% to be provided as a glazed area out of the total floor area in each room, and that is documented in the international building codes. On the other hand, British standard 8206 has a recommendation for a glazed area of about 20% if the room depth is less than 8 meters, and 35% glazing of the external wall if the room depth is more than 14 meters (Wang and Boubekri 2010).

Cammarano et al. (2014) mentioned in their parametric study for the daylighting -in a room that has different architectural features- as shown in figure (1.2) that the proper daylighting design will have an impact on the performance of energy and it enhances thermal comfort levels and the indoor visual quality for the occupants of the building, and designers should make a balance between energy reduction attempts and daylighting advantages. They found that outcomes vary when changing the depth of the room from 3 to 4.5 meters, and the DA would be great if the range of RD is between 3-6 meters. They stated also that the building orientation effect on daylighting amount where WWR and RD should be taken into account; because they tested the effect of WWR which increases the daylight autonomy as it grows up and they concluded that if WWR percentage rises from 0.3 to 0.4, it will generate the highest variation in terms of the amount of interior daylight, and they determined that 40% would provide the sufficient amount of daylight required in a room.

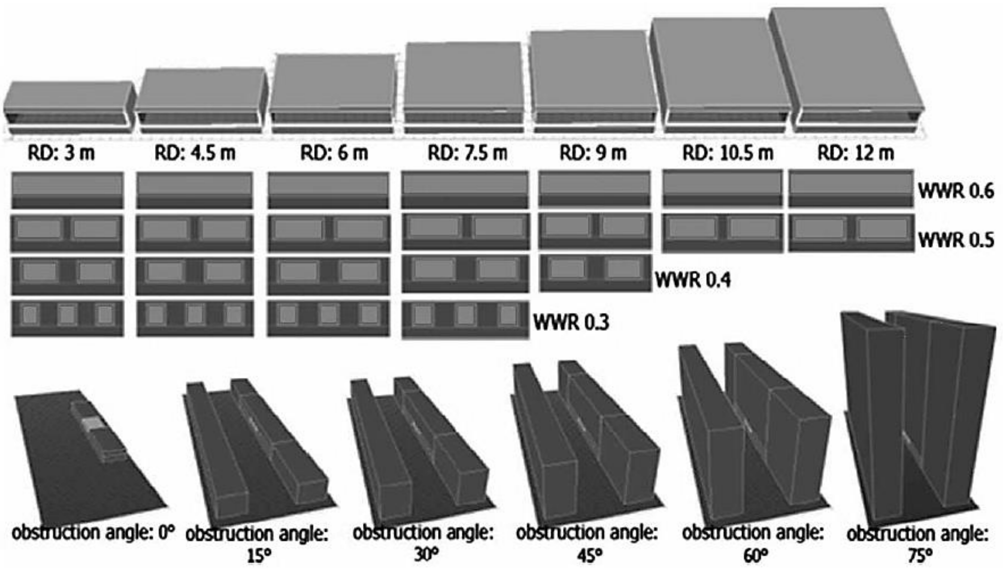


Figure (1.2) Models with different architectural features (Cammarano et al., 2014)

Sudan, Tiwari and Al-Helal (2015) extends the responsibility of daylighting further to arranging the spaces and functions in the building, and it has a significant visual impact on occupants, but it should be achieved without glare, also thermal properties can be managed when synchronizing with the natural daylight. It's a passive component and can save energy for a green building result, besides its healthy features effecting on occupants.

1.4 Importance of daylight at classrooms

Designing with an absent consideration of solar radiations and daylighting penetrating through the windows will heat up classrooms and disturb teachers and students, in addition of creating undesirable flare and glare in the room, and this will simply distract concentration and keep them uncomfortable. Monodraught (2009) claimed that daylighting abundance can effect on the psychological and physical performance of humans, and furthermore, schools should be carefully designed in terms of daylighting. For that, the British school at Abu Dhabi promoted daylight at classrooms through series of sun pipes which provided spaces with natural light that added an exclusive feature that enhanced the school IEQ. Sunpipes were used also in Latifa School in Dubai to bring a filtered natural light in the classrooms with the least heat or glare.

There should be a good understanding for daylighting which is required in each space and its impact on the levels of comfort. This will ease our tasks as architects, designers, and researchers to apply our knowledge and experience on school buildings and help improve in the internal space.

US Department of Energy- Innovative Design (2004) mentioned that daylighting is beneficial and crucially important because it can improve the educational performance of students, it creates a better well-being in the IEQ, and it has a high responsibility to increase student's attendance along the academic year.
If daylighting strategy is well designed, it will help reducing huge amounts of electrical lighting, especially in particular spaces like the gym, food courts, laboratories, swimming pools, and the big indoor lounges where daylighting is much needed in that big volumes.

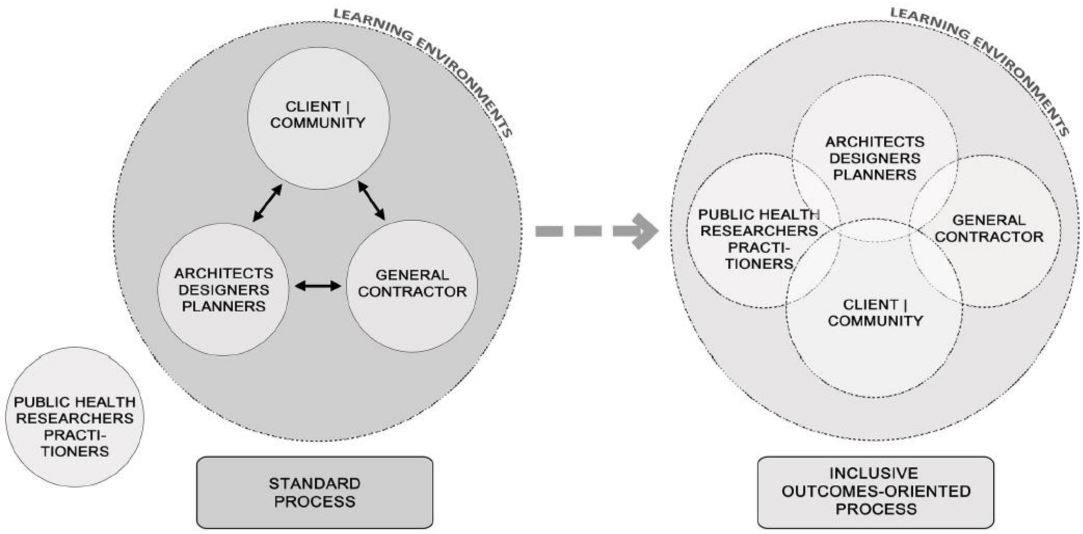


Figure (1.3) Two design processes used in evaluating learning environment (Brittin et al., 2015)

There are guidelines which help improve our design, and consequently our living environment. Many analysis and trials are applied to develop the potential outcome for school design, and as figure (1.3) shows learning environment processes for the standard and the inclusive outcome oriented types.

That explored the possible collaboration between including practitioners, researchers, public health and community in the learning environment and how much it could employ the social intervention in the school projects to integrate all goals and considerations raised from all parties.

1.5 Lighting level requirements at classroom (with respect to depth and height)

Designing a school requires incorporating features of high performance classrooms and administrative areas, in addition to the other spaces. The main goal is to reach levels of lighting in the classroom to achieve the best daylighting that offers an optimal environment for the end-users during the working hours.

Uniformity of light approaching from natural daylighting through windows should be designed and studied with respect to the depth of the classroom; to assure the most balanced and uniform daylighting and it can eliminate the variant darkness and brightness between the different areas in the classroom space.

Al-Sallal (2010) argues that lighting in the classroom would be sufficient in case the level of illuminance reaches up to 300 Lux, and it is conditional on the ratio between size and depth-height of the classroom. In his paper he tested through simulation the RD and mentioned that 4.6 meters is considered as a good depth for a room of 3 meters high. While Cammarano et al. (2014) tested a deeper distance can range from 3 to 6 meters and it can maintain a good DA. There is no doubt that there are many parameters which can enhance the daylighting capacity and efficiency in the classroom, for instance, designing a ratio of 1:2 (height to depth respectively) and providing a 20% of glazing on the external wall of the room will help penetrating an adequate amount of daylight.

Decisive actions were taken after research and development (R&D) and discussions between the field experts. The prepared design manual points that there are certain levels of lighting that should be met to have a well-designed space, and that is listed as follow:

- Educational area -including classrooms and laboratories- should achieve an illumination level of 400 Lux.
- Administrative rooms and service areas –including clinics, utilities and janitors- should achieve illumination level at least 300 Lux.

Internal corridors, circulation areas and muster points are expected to have an illumination level of at least 100 Lux.

This design guide added that the assembly points or any similar function should have 5% of glazing as a minimum of the total floor area; to offer the required daylighting in that instructional space (ADEC 2010). Results obtained by Inan (2013) were notable as she focused on wall to wall ratio. 25% of the WWR penetrated a maximum daylighting from the openings of the wall. That supported her argue about the immense impact of room shape and glazing ratios on the efficiency of space and the natural illumination in indoor environments.

As the guideline also illustrated that Lighting Source Efficacy which is measured by (lumens/watt) should have a range at schools where 110-130 is adequate for the Diffuse Skylight. If compared to the fluorescent which produces 55-90 or incandescent with 10-20 lumens/watt, this means that sunlight is a powerful source of lumens per watt which can illuminate a classroom sufficiently. For that, some designers attempt to use high reflectance ceiling materials and light colors that can distribute lighting to deeper areas, and using other techniques to balance the incident light across the deep classroom (National Renewable Energy Laboratory 2002).

1.6 Structure of the study

This thesis is divided into six chapters beginning with the introduction as chapter one and finalized with the conclusion chapter. The introduction provides information and a background about the study in general and some definitions that help clarify the terms of the research.

Chapter two is mainly the literature review and it concerned about showing many case-studies conducted by other researchers and academics, and it's related to the core of daylighting and energy and classrooms design concerns, then a brief about UAE nature as the location for this research, also it aims and objectives are explained.

Chapter three discusses different methodologies –like computer simulation, literature review and field experiment- employed in previous researches with similar topics, then it analyzes each of these methods to justify later on each of them with certain parameters scheduled in a table; to select finally the best method to apply in the research.

Chapter four will introduce simulation parameters which will be assigned in the modeling stage, and then all trials will be computer-generated to get results then get the best case that will provide a sufficient uniform daylighting and energy saving at the classroom space.

Results will be discussed and investigated in chapter five to compare all simulated scenarios. Chapter six will be the closure and conclude the main findings in the research, and provide recommendations for the whole structure of the research subject and the specific case illustrated along the research.

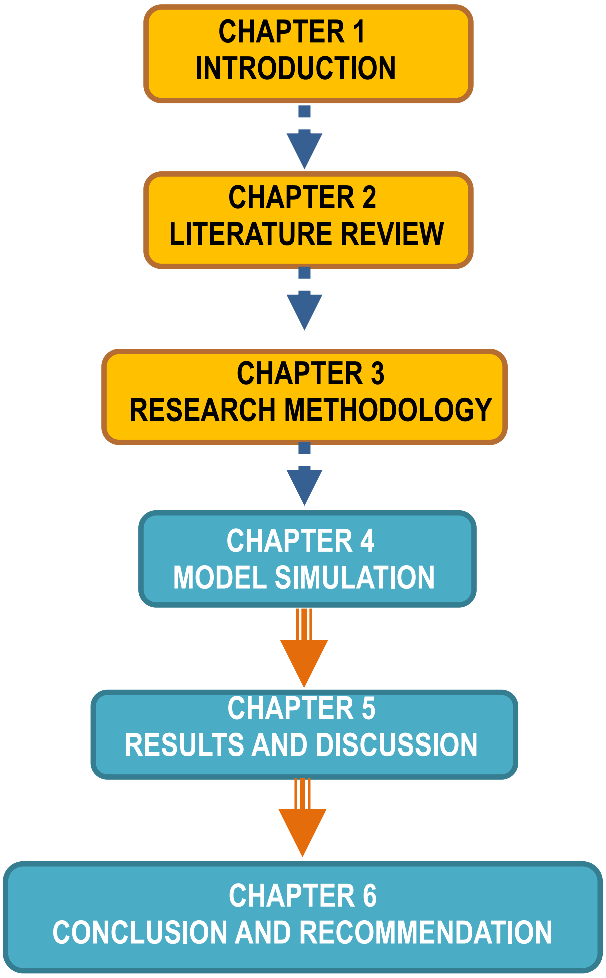


Figure (1.4) Thesis divisions in six chapters showing the research order (Author)

1.7 Aim and Objectives

Schools are essential buildings which are built due to its vital role in hosting students and teachers who spend a significant time there. Building schools at the UAE can be from the ministry prototype or from private investors who eventually must get the approval of their schools from ministry of education. Schools vary in their shape, size and design according to the level of education from preliminary, primary and secondary.

The aim of this research to focus on the main prototypes which are repeated in all the Emirates for both genders and are used for all levels also, and to analyze them in terms of its design with respect to the natural daylighting. Classroom is the main crucial highlight where students settle and spend not less than 7 hours a day. It needs to be well studied and designed to fulfill their psychological and physiological needs in the classroom. Daylighting is an essential aspect which needs many factors to make it successful such as building orientation, glazing proportion, window shape, size, height and numbers, shading elements, ceiling height, in addition to other parts which can enhance the IEQ.

This research is devoted to study daylighting in classrooms from some prototypes and assess its impact on the total energy consumed due to the lighting consumption which effects on cooling or heating loads required to balance the internal building environment. This can be obtained by achieving the following objectives:

- collecting architectural data for the main and dominant schools prototypes which are used through the last decades and consider each of them a benchmark for the initial stage.
- simulate the existing status for the classrooms of the selected schools according to its original materials and dimensions.
- comparing between them all in terms of its daylight input, energy consumption, and other factors.
-Explore the possibility to improve the best case study which has the highest potentials; to get better daylighting, and define more uniformity and distribution in the classroom.
- Examine daylighting configuration and assess the obtained energy performance in the final stage.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

Dealing with lighting is critical and an essential issue in terms of its impact on humans perception for interiors. People sensitivity to daylighting requires designers respond and the know-how to propose an applicable building envelope and a quality indoor space that interacts with the user and maintains the human comfort levels – from heating, cooling, lighting and acoustics- according to the space requirement.

Further information and understanding of daylighting characteristics and its impact in educational spaces were discussed in this chapter, with reference to literature review, more details from previous papers and experiences were conducted to explain more the state of lighting in the space. Many researchers were involved in studying daylighting features, levels of comfort and other factors that would help students and teachers feel happy and energetic to perform well at classroom along the day. Illustrations and opinions of many academics and professionals were convoyed to clarify the related considerations of the classrooms with respect to daylighting.

2.1 Daylighting

Leslie, Radetsky and Smith (2011) differentiated between the elements of lighting. They described daylighting as glare manager because it can reduce direct sun, and daylighting autonomy is designated to save energy and that can be optimized as the need of artificial light will be much less. Diffused daylight defines the work plane percentage which is day lit deprived of an incident sunlight. While average illuminance is considered to be the source of daylight which provides it in the space to complete tasks accordingly. In other words, daylight is assumed to be the percentage of illuminance that occurs on a certain work plane according to the designed illuminance levels. It’s the clear meaning and the master factor for any green building. Energy institutions, councils and their codes are aiming to develop the building daylighting techniques and to encourage enhancing performance for a better IEQ with considerable metrics that can be applied as a rule of thumb for other buildings.

The terminology of illuminance presents in most of the time daylighting, and it presents the sum of light which falls on a horizontal surface and that effect on the visual performance from reading and concentrating on the work plane (Wang and Boubekri, 2010).

2.1.1 Defining daylight, physically and architecturally

There are many terms related to daylighting such as diffusion, reflection, dimming, luminance and illuminance, glare and other elements that results in the process of admitting sunlight into a space. Daylight is a stimulating subject, and a very critical issue since the beginning of the man age, it was used in the Egyptian history where pyramids and tombs were based on the direction of sun and the orientation of the building. Architecturally, daylighting was defined to be relationship between the building form and the natural lighting which offers a visual property in the internal environment, and consequently it provides a healthy and productive indoor space (Haqparast and Ahmadkhani Maleki, 2014).

Lighting is described to be a form of energy which inspires and motivates our sense of vision. They clarified that having a well naturally-lit space would improve occupant's performance, and if the same is badly designed and daylighting consideration is absent, many problems will occur from concentration, health, and vision issues. It can increase the productivity and improves the psychological behavior of employees and users of the space (Kamaruzzaman and Zulkifli, 2014).

Daylighting is simply the natural source of light which provides a visual comfort that improves the IEQ, and it improves thermal comfort levels for occupants. It helps rendering the space and index for a better lighting achievement which passes through skylights and glazing (Singh and Garg, 2010).

Windows are critically important in any space where they offer daylighting, provide a view –which is desirable for most of the users- and helps getting the sense of orientation, it's a connection between outdoor and indoor environment, it provides fresh air and plays vital role to balance the room thermal status for a more relaxing and healthier atmosphere.
Several numbers of glazing solutions were offered to manage glare and flare issues, and solar overexposure, in such like blinds, curtains, louvers, reflectors and light shelves. Skylight and solar tubes are means of natural and economic trends of lighting buildings.

Daylight is a component which effects on the visual response of humans and can make better activities in the same space. Daylight factor (DF) is a considerable factor while designing a building to evaluate the satisfactory internal natural light for the inhabitants, and it's affected by the orientation and surroundings which decide the final vision. DF consists of sky component (SC), External reflected component (ERC), and internal reflected component (IRC) where all of them are combined to create the daylight factor (Sudan, Tiwari and Al-Helal, 2015).

2.2 The ergonomic (physics) of light (terms)

2.2.1 Energy & Daylighting

The relation between daylighting the energy consumption and saving is critical and should be designed precisely; to avoid any risk of glare and flare or overheating in the building, and to enhance its potential.
Manzan and Padovan (2015) described the European Parliament definition about the building performance -and it's documented as 2010/31/CE- to be the total energy amount essential to run a building according to its typical usual use including cooling, heating and lighting. They classified many attempts done to understand the relation between energy and lighting; especially that it's been an attraction for many researchers. Some of them found that daylighting does not only reduce energy consumption discharged by electrical lighting, but also it improves

the heating and cooling loads in the building. Also by computing some projects through simulation, Manzan and Padovan (2015) argued that designing with accurate rules and ratios –particularly window-to-wall- will help reducing the total energy consumed annually, with considerable effect of external shading elements which can be moveable. Also experimenting different parameters from orientation and geometry of building to integrating photovoltaic system and shading devices had pleasing results and good conclusions that helped updating the knowledge about this interaction between daylighting and energy performance.

Parise and Martirano (2013) state that energy saving can be achieved by controlling daylighting coming into the interior space, and optimizing the characteristics of harvesting daylighting should be integrated with a lighting system that is fitted with dimmers and switches to make the best impact on energy saving. They assumed that embracing a Building Automation and Control System (BACS) can provide a management system that helps integrating the existing status of a building with energy saving strategies, and will document all needed data for better diagnostics, safer operation and easier maintenance.

Oh, Lee and Yoon (2012) admitted that solar radiation can only find a direct penetration only through windows, and shading devices will be needed consequently. They focused on the blinds application in this study, and discovered that 24.6% reduction in energy can be reached when using a double-sided blind with the presence of a control for lighting dimming with comparison to the base case, in addition to a recognizable drop of the glare in the indoor space. As the renowned architect Ken Yeang specified in a personal interview in 2016 that design should be done to the optimum by using the proper glazing system and shading devices to block the undesired sunlight from the space. He added that integrate the latest technologies in buildings is a smart way –like using glazing which has a series of nano-layers and it tracks the sun across the sky, then it turns the color to a darker tone- leading to a healthy space that makes people comfortable and relaxed while working along the day. Sozer (2010) claims that energy efficiency is reliant to the building envelope which is the exchange factor between indoor and outdoor environment, and it has a great impact on the building performance and total energy consumption. She noted that 12% of the total energy of a building is consumed for lighting. This can be managed while providing comfort levels in the building for users through many applications that helps the building to be technically passive.

Thompson, Donn and Osborne (2011) emphasized also the credit of daylighting not only to improve inhabitants' health, but also to reduce energy and keep the building more sustainable and green. Daylighting can remarkably decrease artificial light loads and consumption up to 80%, while in some buildings cases it can reduce half of that consumption. Internal load also can be saved up to 40% which consequently will make a good saving in cooling loads as well as the saving obtained from lighting. Abu Bakar et al. (2015) argued that 32% of energy is used for HVAC and 25% for lighting commercial buildings out of the total needs as shown in figure (2.1). This pie chart shows that more than 50% of the total energy consumed is combined only in lighting and cooling the building, and it's considered a huge amount that should be considered in design process.

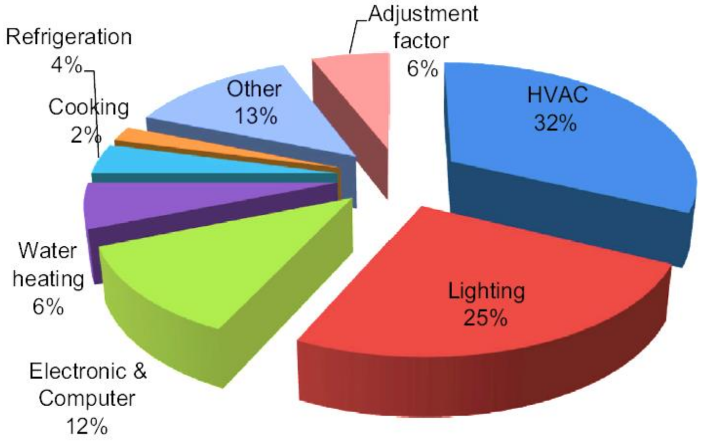


Figure (2.1) Energy End use breakdown of commercial buildings (Abu Bakar et al. 2015)

National Renewable Energy Laboratory (2002) described the building envelope as an element of design which is responsible for 10-20% of the energy consumption at schools. Insulated walls and ceiling are critical indoor components which can decrease heat loss and gain, also can enhance comfort levels in the classroom. The lighter the chosen colour for external walls the less absorbed heat in the indoor space and so does the roof. This will reduce the needs of HVAC system and make use of the building material. Windows should be designed and treated with light shelf, blinds, or any glazing elements that helps in providing the proper lighting levels which penetrated to the space, and they are recommended to be low-e glazed to achieve a better efficiency for the building.

2.3 Designing classrooms with daylighting

There are many key features which are considered while designing a school, and they have a drastic impact on the students and teachers performance. One of these major factors is the daylighting, and it can increase grading results and students attendance.

There should be a careful study when deciding to combine artificial and natural lighting in the same space (National Renewable Energy Laboratory 2002). Artificial lighting distributes more heat than the sunlight, and that heat should be removed through using a passive or active ventilation system – means more electrical loads- then more annual cost will be paid.
Windows should be designed for a high performance where the least heat gain or loss will occur. Proper design for classrooms can make a well-balanced environment for students to learn, and a healthy space to spend the class time with a high performance and effective focus mode.
Samani and Samani (2012) illustrated in a bubble sketch as shown in figure (2.2) the relation between three tiers that are considered in controlling lighting quality.

It is based on individual well-being, economics, and architecture. Many values are important to reflect in the final lighting result like visibility, mood, health, activity, design composition, style and form, installation, operation, energy, and environment.

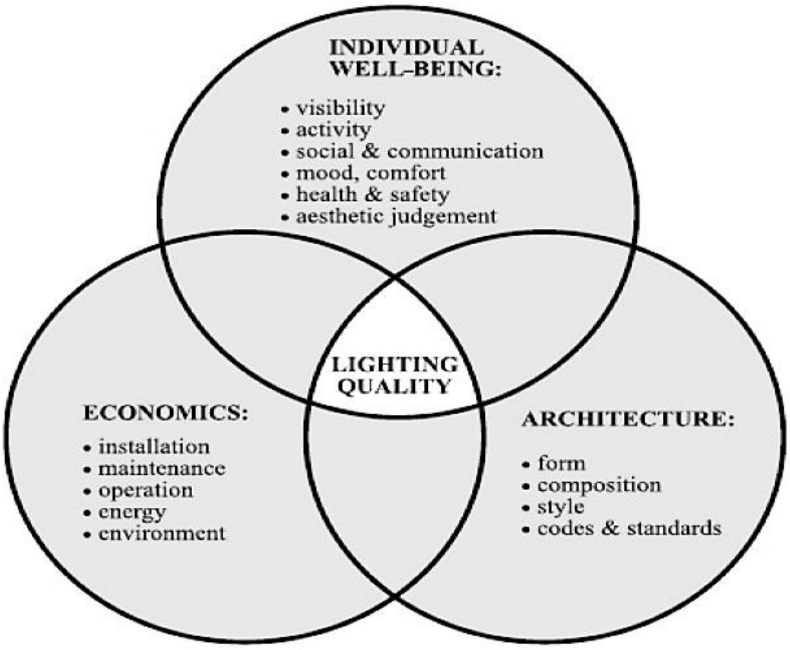


Figure (2.2) Elements for lighting quality (Samani and Samani, 2012)

Orientation is an important factor that should be studied, to get the maximum efficiency of design with the help of daylighting. Working on the east-west axis is a winner step to improve solar accessibility to the building, and that is be applied to most types of buildings regardless their variant characteristics and that contribution that will increase the internal quality of the space whether it's an educational, administrative or recreational area. Daylighting aperture should also be considered; so it can cut the beam radiation which gets into the room at the midday where heat is at its optimum. For that, North glazing – in general cases- is considered as the best direction for glazing; as it doesn't produce heat through windows and it helps introducing light for a better incident sunlight.

Light shelf was described by Freewan (2010) as a horizontal or a leaning plane which is projected over a window, and it's installed either internally or externally or both of them in some cases. It is labeled as a key element which can block the direct incident sunbeams and improve uniformity of daylight within a space, in addition to its ability to supply narrow room –that has a depth between 4.88 to 6.1 meters- with a good lighting. It's helpful for the schools designed as multi-story. National Renewable Energy Laboratory (2002) mentioned that light shelf can control direct sunlight in the southern windows as shown in figure (2.3) and it can reflect amounts of light which can bounce up to the ceiling and provide a good lighting for a classroom with a depth of 20 ft which is equivalent to 6.1 meters.

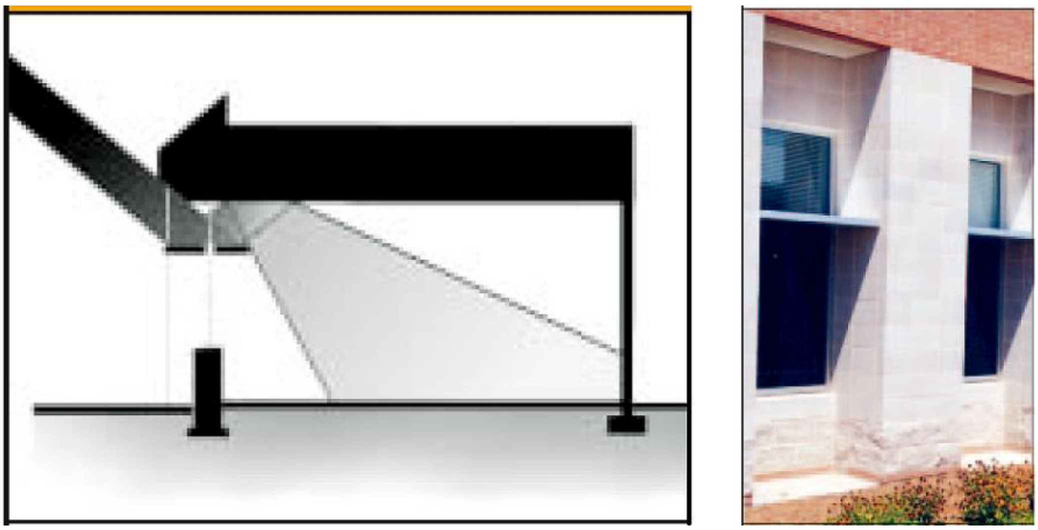


Figure (2.3) Light shelf controls direct sunlight
(National Renewable Energy Laboratory 2002)

Light shelf is considered the best solution to harvest the south solar radiation with the least heat gain or unwanted radiations. Lim et al., (2012) proofed that light shelf can increase daylighting with a uniform and well distributed range, nonetheless it couldn't reduce glare from the direct sunlight. Light shelf material should be light and reflective to bounce light into the room, and it supports lighting up rooms which are 6.1 meters deep and also can be used in multi-story buildings. Merging blinds with light shelves can be useful in case of the south façade glazing, and reflect light more into the space.

Roof monitors and clerestories have special characteristics which make them unique and desired in specific school designs. They distribute light uniformly and evenly in the room, also they reduce glare. Roof monitors maximizes the penetration of daylighting within the school spaces when integrated with the building in the south-facing side. Designing with such monitors and clerestories should be simultaneous with the dark spaces in the classrooms where projector and boards are fixed. They help reducing the contrast between bright and dark areas in the classroom. Overhangs are also recommended to be used for summer time as they reduce radiations in the warmer months and it's capable of taking full advantage of the winter gain (National Renewable Energy Laboratory 2002).

Wang and Boubekri (2010) in figure (2.4) provided a map showing the positions of the users in a certain room where there is a sun path through a full height window, and it shows the poor or good performance in terms of reading or analogy. And they claim that these zones have no distinct with respect to the distance from both sunlight direction and window.

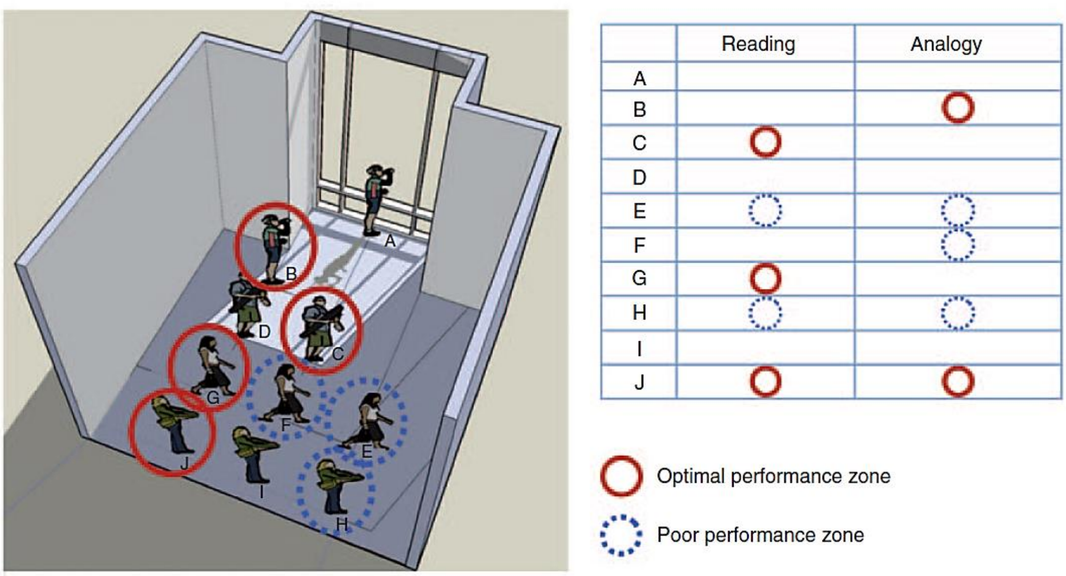


Figure (2.4) Locations of students showing their performance level accordingly (Wang and Boubekri, 2010)

Department for Education (2015) pointed out that lighting must meet each room’s requirement according to its function. And it should be adequate in classrooms to provide for students and teachers the optimum visual comfort. Avoiding glare is an important highlight. Views from inside to outside should be in a clear way, and consider eye strain issues. It also proposed other means of security for outdoors and emergency cases but using the artificial lighting which is not part of focus in this research.

2.4 Design Strategy and Parameters

2.4.1 The study Location

UAE as an arid hot region has always been famous with its original buildings which were erected with the local materials from coral stones, sand, clay, palm trees, and other construction materials. Old fortresses and houses of the Sheikhs are still standing icons and a current proof of sustainability which was applied in the elements of design like the Barjil to collect prevailing wind, internal courtyard to ventilate the house day and night according to the pressure differences, narrow and thin windows, modular structure and using light colors to reflect heat and solar radiation as much as possible (Dubai Municipality, 2011).

Figure (2.5) United Arab Emirates location map (Google 2016)

The United Arab Emirates (UAE) is positioned between latitudes 228–24.43°N and longitudes 518–54.65°E as listed in figure (2.5) above, and it's a flat land which is elevated above the sea level 27 meters. Being located on the tropic of cancer (248N) results in receiving the highest rates of solar radiation along the year. Emirate of Dubai –where simulation weather profile will be conducted- is located in the centre of the other Emirates where it's connected to Abu Dhabi from the south-east, while Sharjah, Ajman and other Emirates are connected from the northern part as shown in figure (2.6). Dubai is an international commercial hub where business and tourism are vital sources for the city, and people are attracted for its unique architecture and living lifestyle.

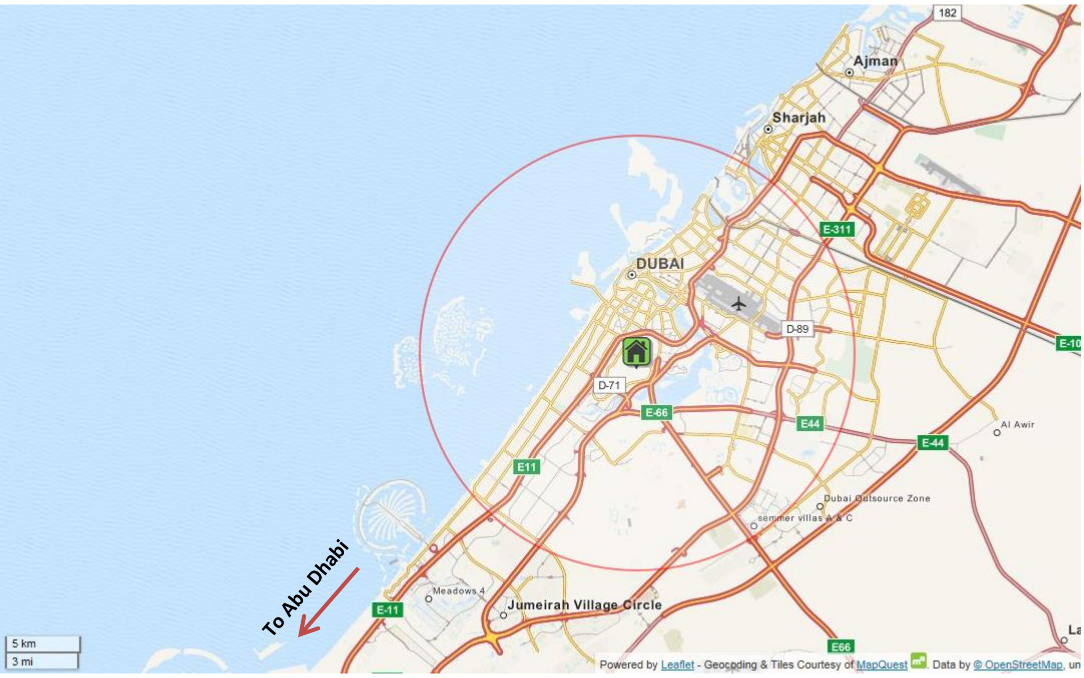


Figure (2.6) Dubai location with respect to other Emirates (IES 2015)

Abu Dhabi is the only Emirate available in Climate consultant, and because it's close to Dubai, it will be used accordingly. For Dry bulb mean table as displayed in figure (2.7), it recorded a range between 13- 41 °C while the wet one varies from 12-27 °C.

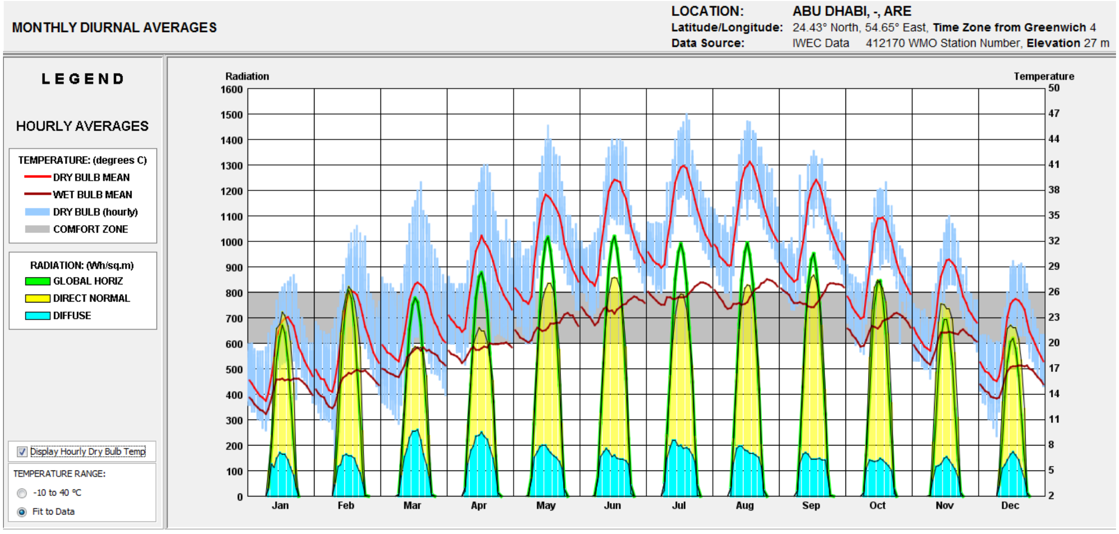


Figure (2.7) Monthly Diurnal Averages- Abu Dhabi, UAE (Climate consultant 5.4)

Figure (2.8) indicates comfortable months which are available from December to March at day time, and extends from October until April at night time. For temperature in the UAE, the peak value is 47 °C in July while the minimum recorded 5 °C in February. Regarding the mean relative humidity, it reaches up to 60.6%, and the prevailing wind is coming from the E of N 333.5° hitting an annual speed of 3.6 m/s.

The value of annual hourly mean global radiation is 250.2 W/m2 and the mean daily global radiation is about 6000 Wh/m2. In such a harsh climate, UAE is characterized by high levels of solar radiation and intense annual sunlight where 2192 kWh/m2.yr is received from the solar resource and the cloud cover is low as 1.4 oktas (IES weather data 2015).

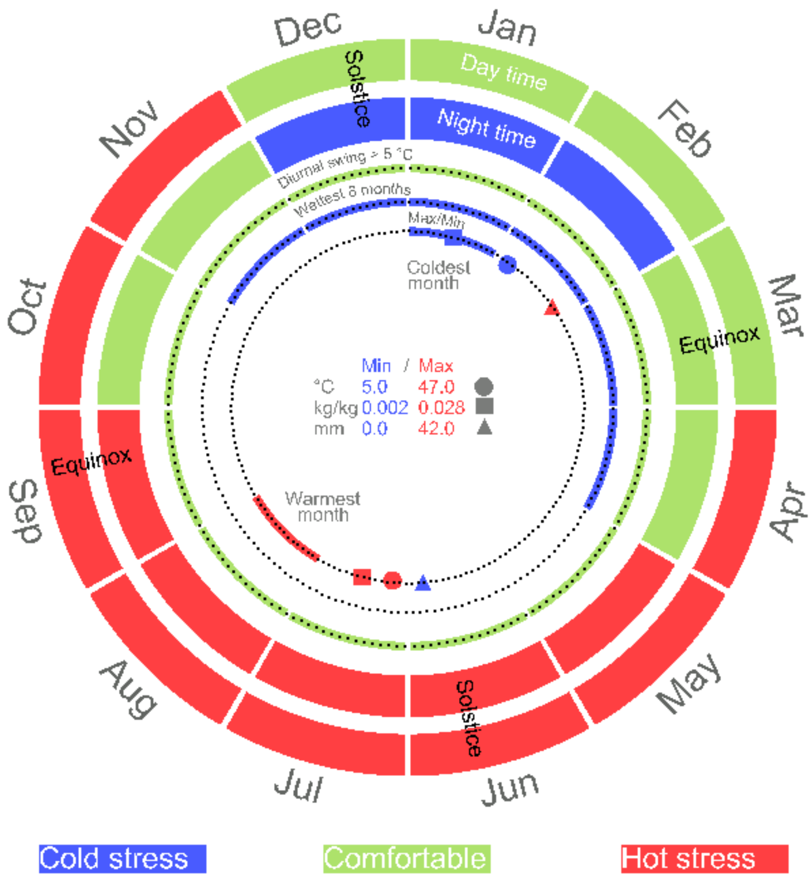


Figure (2.8) Climate Summary Metrics- Abu Dhabi, UAE (IES 2015)

There are many regulations which are documented to improve the existing status of buildings to make them green and to sustain for a longer time. The Emirate of Dubai legislated rules for buildings in Dubai; to enhance the performance and mitigate consumptions emitted from water and construction materials. This is a vision to improve the comfort level of inhabitants and to create a healthy city which has a better impact on the environment.

Dubai has a comprehensive goal to make all buildings green. Therefore, they have conditional rules for the big projects which are mainly on a larger scale like exceptionally long tower, hospitals, huge malls…etc. There will be some rules which apply on them specifically to study the case and make it properly done as a reasonable effective building.

But as a general rule, daylighting is considered an important factor that should be available in the majority of the buildings to gain natural lighting but with the least heat gain. This guideline regulated that daylighting should be provided from a skylight or a glazing part to illuminate the interior space, and fitting the building exterior spaces with automatic control system which should be paired with the daylighting to lessen its operation at the day time. Also, natural light is a must in all new buildings; and that will help decrease the amounts of energy consumed from lighting up the spaces, and will help occupants enjoy a healthier IEQ accordingly. The view is an element of design which must be achieved; this means that each of the office and residential buildings should provide a line of sight to the outdoor area as a regulation for a better indoor space. Noticeably that proper windows design should minimize direct sunlight and be fitted with shading devices and provide a balance in the indoor space lighting.

For lighting control advantage, one recommendation is proposed as follow: In case of having an office building which is designed deeper than 6 meters from the windows, its obligatory to fit the lighting system with a sensor to be able to adjust the electric lighting level according to the optimum value. Add to that, when there is a combination between natural daylighting and artificial one, the working plane must be within the range 400-500 lux as a level of illumination required in the office building floor.

Schools in the United Arab Emirates and the ministry efforts to improve prototypes to be more adaptable and practical, and sustain for a longer time with the highest efficiency. Many factors are responsible of designing a well-thought of school like shape of the mass, number of floors, orientation, classroom size and height, windows direction and size, glazing to floor area, desk position and daylighting direction (Al-Sallal, 2010).

Fang et al. (2014) argues that thermal performance is considered to be the most influencing factors on energy consumption, and combining that with the building envelope –specifically walls and their insulation- will validate creating more comfortable thermal space internally, and deduct the amount of energy consumed for heating or cooling the space.

Lim et al. (2012) Consider that daylighting is an affordable resource which can be harvested by installing proper glazing and enjoying a free source of light. It is a passive strategy to be optimized and will decrease the energy consumption of the building. They also mentioned that in a tropical climate –like Malaysia- the challenge to get a daylighting will be accompanied with solar radiations -which can reach up to 130 klx- and that will overheat the indoor space and increase the heat gain level. Any they argued that uncontrolled daylighting will cause undesired glare on the working planes making discomfort for the occupants. Solutions in such similar weather condition would be thoughtful and inspires solving related issues.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Methodologies selection, outline

Evaluating building envelope and its impact on energy performance at schools is an interesting subject that many researchers aimed to explore more in this field and determine some basic indicators and guidelines which can be used by professional as an accredited experience and knowledge, or could be a bench mark for other researchers to work on it cumulatively. Some methods have accuracy level which fits the research approach, and it can be decided through the process of choosing the paper theme, its details and the promised results after applying the certain methodology.

Methodology is a skill that is selected to identify the classrooms existing characteristics, problems and the possibility to study its design solution, and for that, some research might go for more than one methodology to proof the given results and back it up with reference to other researchers' practical experience in the field experiments, based on simulation and computer evaluation, or supported by literature reviews which can gather huge information from various destinations and experiences.

This research more attractively is willing to review the different method that have been used in similar subjects through various papers then the selected methodology will be used to assess daylighting impacts on the performance of end-users and energy consumptions at UAE ministry schools which will be introduced intensely in the modeling chapter.

3.2 Different methods used by previous papers

3.2.1 Computer software simulation methodology

Abdelatia, Marenne and Semidor (2010) investigated daylighting strategies for sustainable schools in the existing classrooms prototype in Libya. There is a climatic common between the UAE and Libya where they share the tropic of cancer and the sun performs vertically at its culmination, and this makes this casestudy more valid to apply in related countries. Abdelatia, Marenne and Semidor (2010) mentioned that there are several methods which were used to measure amounts of glare which results from natural light; nevertheless, there isn't any method to inspect both artificial and natural lighting sources to affect the glare. Calculation was done using DIAL-EUROPE for daylight factor (DF) which occurs in classrooms. Scale model simulation is used to evaluate the daylighting in indoor spaces. They designed a typical classroom with respect to its original environmental aspects, and then they checked the amounts of glare on the walls, chalkboards and the students' desks.

Alaidroos and Krarti (2015) experimented optimal design options which can be obtained through the building envelope for residential purposes in KSA. The study aimed to evaluate buildings envelope essentials like wall and roof insulation, windows glazing, shading and area and thermal mass properties that can moderate energy consumption. Reading and evaluating was processed in 5 areas that have different climatic zones.

In this simulation EnergyPlus software was used to perform simulation for the building energy. They consider it an accurate method compared to "weighting factor" which is not recommended in evaluating advanced systems. They simulated a single family house to assess its efficiency and energy performance; also they came up with a conclusion that 36% saving can be acquired within the lifetime of a residential building.

Labib (2012) needed to proof daylighting improvement in current buildings with the help of Laser Cut Panels (LCP) using Radiance software and Evalglare to test and evaluate the luminaire values. There were 3 simulations performed for classrooms located in New Jersey, USA; to evaluate daylighting enhancement possibilities when adding (LCP) in the windows. He tested DF, glare and illuminance in those classrooms then he concluded this research by breaking down all results obtained in simulation.

Manzan and Padovan (2015) carried out a simulation for the daylighting that can be optimized for office building which have moveable and fixed shading devices in Trieste, Italy which is considered a sunny area. They considered heating and cooling, in addition to the energy required to light up an office space with the help of shading devices. Many software were used to perform this simulation as ESP-r to calculate energy, ModeFRONTIER to synchronize simulation outcomes to get their best resolutions, and DAYSIM to analyse daylighting values.

Mangkuto et al. (2014) performed a simulation to compare between daylighting performance in real windows and virtual atmosphere which is so-called Virtual Natural Lighting Solution (VNLS) in a certain space in Netherlands. The room was selected and modelled to be evaluated with the aid of Radiance software, Hdrgen and Evalglare. Comparison covered illuminance, dayglighting uniformity and the space readiness.

3.2.2 Literature review

The paper used literature review to study the relation between daylighting and accomplishing energy saving level in the buildings in Malaysia. They analyzed the collected data which focused on electricity used in buildings and how it can be reduced by the help of daylighting. Researchers mentioned that journals and online searching were used to get the required data for this paper (Kamaruzzaman and Zulkifli, 2014).

Samani and Samani (2012) discussed indoor daylighting influence in the educational institutions and its impact on students' performance. They checked the productivity of students and improvement results which can be obtained at the presence of daylighting. In addition to literature review, this paper added used a research which was a survey took place in Alpha course, Malaysia from hundred fifty students. They interviewed also 2 experts in this field to comprehend their research.

Hemsath and Alagheband Bandhosseini (2015) mentioned that building geometry has an impact on the building energy performance, and it can minimize consumptions according to the shape of the building. Geometric method was described for horizontal and vertical proportions to get the findings and compare it with the materials chosen in certain case studies. They gathered recommendations and guidelines and then they analyzed them using stacking and aspect ratio. Accordingly, they discussed the relation between building form, orientation and glazing to influence the daylighting amounts entering the space.

Brittin et al. (2015) conducted a search based on comprehensive reviews regarding schools -from K-12- in terms of physical design properties and architectural guidelines. Relation between students' activities and the school environment was also discussed; to engage all related developments to provide a school design founded to improve wellbeing and IEQ. Qualitative review was also directed in the research to enforce the strategies collected and codes gathered from different databases.

3.2.3 Simulation and field measurements

Inan (2013) combined between simulation and field measurements, and she argues that field experiments are more accurate and effective to get results related to illumination and daylighting values. She investigated the natural illumination properties in the northern hemisphere in one of the architectural classrooms at Izmir in Turkey. For this, Velux was used to compute lighting factors at different directions and floor levels for the classroom. LT-Lutron LX-1108 is a luxmeter which was used to gauge the variable DF with reference to the changing window model.

Lim et al., (2012) chose the field measurement in their investigation for daylighting in office buildings. Their goal was to assess building façade impact on daylighting quality and how much its design can change the values obtained. A room which is facing south-west orientation was selected in a governmental building (WPJB) in Malaysia as a sample for the trial. It has a deep plan with a ratio of 2.2 –depth to width- and adjacent surroundings were partially excluded in the evaluation. Delta OHM LP-PHOT 02 and Probe E were installed in the room to assess illuminance values. In addition to this, they used Radiance software to compare its results with the values obtained in field for the lighting illuminance and performance in the office building.

3.2.4 Field experiments

Sudan, Tiwari and Al-Helal (2015) experienced DF model for the windows oriented on the eastern wall in a building under clear conditions of skies in the Indian region in Varanasi. Solarimeter was used in this paper, then they took points and validated a room to evaluate the obtained calculations of DF, MATLAB10a programme was only used to shorten the time for mathematical calculations. After that they compared SC and IRC values which are related to sky components and internal reflected components percentages respectively.

Fang et al., (2014) studied building envelope in terms of its influence on insulation properties and how much energy can be reduced in summer time. The experiment took place in Chongqing, China which is a hot city similar to the UAE climatic conditions. Two chambers were constructed to assess external walls insulation and compare the indoor thermal results between both of them. Air conditioning system was used to in the rooms, thermocouples to collect data, potentiometer, a recorder and a computer to document all required data.

3.2.5 combined survey and simulation

Al-Sallal (2010) identified the problems related to classroom by surveying design information collected from the schools in UAE and data were collected for analysis and discussion. That helped him to study the classroom windows dimension, direction, orientation, position and distribution of desks. He used Radiance as simulation software to work on further details on the building materials and design to obtain faster and accurate results.

3.2.6 Other methods:

3.2.6.1 Development of the scale models

By constructing a model for a typical room using plywood at a scale of 1:10 and placing the model in a real condition to evaluate the illumination occurs in the room in all stages. Predictive tools for evaluating daylighting performance of light pipes took place with Ahmed et al. (2006).

3.2.6.2 Time-segmentation method

This method was used to represent time – which shortens the year to smaller periods to ease calculations- and weather considerably in a summarized form and that would help them to learn more about daylighting and to check the best strategies to let sunlight in the building spaces. An intuitive daylighting performance study and optimization method was done by Andersen et al. (2008).

3.3 Selection of research methodology

Literature review is a conventional approach that is based on collecting knowledge through others experiences. It's established by gathering information from papers, journals and books. This field is huge and researchers are so interested in getting clear facts about daylighting and its impact on energy performance. Reviews are good when people can use them as a ready source of information; especially after the advanced technology of searching online, and the e-resources which can provide tremendous and valued papers to support researchers achieve their goals in a short period of time.

Yet, not all details can be obtained only by the literature reviews because of the different interests of researchers and it can't be found in a one paper. Collecting data required for a certain subject may take longer than what's expected to analyze and conclude the research, meanwhile information could be outdated. This approach needs immense efforts and concentration to collect and make a proper research which should be eventually organized and well prepared.

Computer simulation is a method carried out with the aid of computer machines. It performs a technique which helps creating a virtual environment that imitates real conditions on a programme instead of applying that in reality. Simulation is a time saver which reduces the period of applying the experiment instead of preparing a room in field or collecting data to begin a research. This approach is highly flexible that enables researchers to model any form of a building with many duplicates can be created in one click, and downloading related as data like weather; to make different trials for the model with different modes and regions. Software which are related to daylighting and energy evaluations have thermal, building construction and climatic conditions which reflect the real life conditions and can be created accurately. It simplifies comparisons between different models by merging them in the same file and get energy values, electrical loads, CO_2, DF, heating and cooling. Simulation is a fast and speedy practice which comes up with many variables. Some software are free to download and others can be obtained with fairly cheap price that is affordable for many users.

Some software may have errors and shut down during drawing or simulation process which will increase the timeline for a research. In the other side, not all software are accurate when some inputs are out of date like weather and materials, and this case results will not be valid. Some real-life details are ignored in some software simulations and that decreases the credibility of results.

Field Experiment is an actual picture for the real site conditions. Climate and measurements are fairly accurate and the available equipment are highly precise. It’s capable of calculating noise, lighting lux, visibility, glare values and heating levels in the room. Experiments can show the correctness of the collected literature reviews which can validate it more.

A noticeable issue in field experiments is the cost of equipment which are sometimes high and unaffordable on the personal level, and may need sponsorship. They require frequent maintenance and calibration to stay accurate. Also, many variables are not considered by researchers at site which does not give a highly correct result on the desired factors. The main problem of field experiment is time consuming to collect data along the experiment period, and that is exhausting and spends more money to record equipment.

3.4 Selection of simulation software

Specifying the part of interest in research defines the required software required to conduct that aspects. Programmes related to modeling can vary from many companies an according to the region. Some software like AutoCAD, 3ds max –from Autodesk- and Sktechup –from google- are handy tools to draw and model the required building to be ready for advanced simulation stages. Integrated Environmental Solutions (IES) Virtual Environment (VE) is energy analysis software which studies energy performance, CO2 consumption, thermal comfort, illuminance values, glare levels, in addition to other important variables required in this paper. It supports the gbXML type of files and its based central simulation building model operates to make it totally integrated by its own. IESVE is the standard software in the UK industry; due to its competence to simulate HVAC systems with a cutting-edge level, add to that the building passive effects that can be assessed.

Other energy software are also common and have many advantages like EnergyPlus, Ecotect, IDA ICE RIUSKA and eQest. But compared to those software, IES is considered the easiest user interface, and supports many formats, and in overall, IESVE is very common in the market of the UAE as a friendly software to use. Add to that its availability, and the feasible price to buy. Author is used to work on this software which makes obtaining data through it much faster and this will save a detectable time in research. Inan (2013) based simulation process using Velux to evaluate daylight; meanwhile other used DesignBuilder as conducting software like Supansomboon and Sharples (2014) and Hong et. al (2012). IES can produce these results using FlucsDL from the DF menu which will help us know how much illuminance available in classroom and on the students work desk.

Simulation will be carried out according to the main solstice periods, equinox, and the sun vertical overhead dates which will be along the year time (Supansomboon and Sharples 2014). Simulation will take into account the students attendance period that range between 07:30 and 14:30, and it will be conducted in 2 periods for each simulation process, one in the morning and another at the afternoon time; to evaluate the maximum and minimum sun angle along students and staff school day.

Table (3.1) Comparison between the nominated research methodologies (Author)

Criteria/ Method	Literature Review	Computer Simulation	Field Experiments
Time	Period to collect information and data is quite long	Capable of compacting time due to its quick process, and can simulate and time of the year in any region.	Requires collecting in certain timing (day, night or both) and seasons of the year.
Coast	Many resources are available for free, some e-journals and papers need to be purchased, yet low-priced.	Annual purchasing price is affordable and cut-rate for students and academics.	Consumes money for renting or purchasing gadgets and measurement equipment.

Criteria/ Method	Literature Review	Computer Simulation	Field Experiments
Accuracy	By time, data in some papers and books turn outdated or revised.	Has an accuracy level, as used by experts concerned about daylighting and building envelope.	If well installed and calculated, results will be precise and reliable.
Pre-experiences	Needs an experienced research who knows how; to collect data and analyze them professionally in a compacted time.	If software is experienced, getting results will be an easy step.	Using tools and equipment needs some tips and instruction to obtain correct results.
Remarks	Compressing the research time will help reducing the problems of invalidity of knowledge.	Certain Variables need to be validated with the existing status, or compared with some literature review.	Equipment should be Maintained frequently to insure precision, calibration helps stabilizing accuracy.

3.5 Methodology framework and research parameters

The research will be conducted in the UAE climatic conditions for ministry schools existing all over the Emirates. There will be many parameters needed to build up the research structure; to proceed with expected results of simulation. Some parameters are variable while others will maintain the same along the simulation procedure. That will clarify the changes occurring within the investigation.

Permanent parameters:

Weather data file

The selected location for the research is in the United Arab Emirates where the ministry schools are in the range of all Emirates and for all education levels and genders. Indoor space quality is important for students and teachers to have a proper healthy environment which helps them concentrate and enjoy a full education day without any visual, acoustic or health issues. Lighting data will be constant with reference to the given data.

Timing

Students in ministry schools commence their day at 7:30 and stay at the building until dismissed by 14:30. They start their weekday by Sunday till Thursday; then Friday and Saturday are off days. That period of time will be used to perform simulation along the entire process and stages.

*** Variables**

Building envelope

It's been discussed through many paper the importance of building envelope and its impact of both daylighting and energy consumption. This aspect will be under testing to assess its capabilities to reduce visual problems, or to enhance the levels of energy performance.

Classroom dimensions

There are many researchers who checked the proportion of the room and how much it can let the daylighting in. depth of the classroom is a considerable matter which lead to light and dark areas, and that should be balanced to help reaching to uniform space. Quality of light coming into the room is crucially important to be selected according to its function.

Orientation

One of the major parameters that decide effectively success of failure of the building is its orientation. Schools – and classroom in detail- should be designed with reference to the best orientation where no much sunray entering the space, yet a good lighting is provided in the classroom. It has a direct impact on the energy consumption which can be reduced if correctly located. All cardinal directions will be tested to check the best in delivering light and energy saving simultaneously.

Building construction materials

The choice of materials according to the base case will be at the first step, then enhancing that materials will be a matter of discussion to check which fits more to help improving the IEQ in terms of daylighting. IESVE has the majority of materials required to conduct simulation, for that, results are understood to be valid and help represent the existing status and the possible improvement.

Table (3.2) Scenarios applied on new base case according to variable parameters (Author)

Element	wall aspect		Materials U-Value			Window	
Parameter	height to depth ratio	window to wall ratio (WWR)	wall	roof	Window	Height/width ratio	Glazing Position
Base case	base case value	base case value	best base case value	best base case value	best base case value	best base case value	base case value
Attempt 1	(1/2)	20%	Dubai Municipality	Dubai Municipality	Dubai Municipality	(1/2)	Flush outside
Attempt 2	(2/5)	30%	Estidama **1** pearl	Estidama **1** pearl	Estidama **1** pearl	(1/1)	middle fixed
Attempt 3	(1/3)	40%	Estidama **2** pearl	Estidama **2** pearl	Estidama **2** pearl	(2/1)	Flush inside

3.6 IES-VE Software Validation

As integrated modeling and simulation software, IES is responsible for setting up the virtual environment that imitates the real status of design, materials, climatic conditions and the working hours at the building. Using such software has privileges where there is and ability to create the proper virtual environment without the need to move from your workspace, and all desired variables can be computerized with the least effort by changing the parameters and options in the model scene and notice the changing values and results. All weather data are controllable, and timing of simulation is flexible to accept the required working hours, weekends, vacations, and holidays and as required in the case of the school. Azhar, Brown and Sattineni (2010) argued that IES could define the building energy performance and provided an illustrative analysis for heating and cooling loads, in addition to the CO2 levels and other facilities which were obtained automatically.

Barbhuiya and Barbhuiya (2013) considered energy consumption and levels of thermal comfort in the educational building in UK which was their main concern, and they were able to compare between simulation results by using IES. They monitored daylighting and the indoor thermal levels. (Shameri et al., 2013) conducted the daylighting where the worry was about the double-skin façade in the office buildings to check the human comfort in 12 existing systems. All DSF systems where tested in different climates using IES, and they concluded the paper illumination and lux levels based on results acquired from the software.

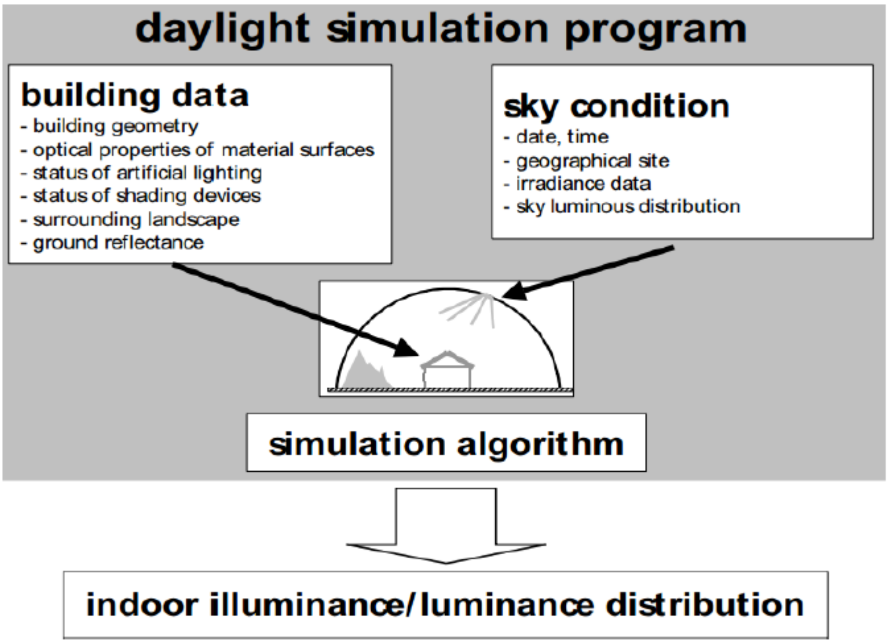


Figure (3.1) Basic modeling elements for daylight simulation (Haqparast and Ahmadkhani Maleki, 2014)

Simulation software helps analyzing the possible potentials that can be delivered from a certain building space or a comprehensive building study. Either of these programmes should have two main inputs, building data and the sky condition as shown in figure (3.1). Building geometry, materials properties, artificial lighting status, shading devices, landscape and ground materials are important input records in the software, also the date, time, geographical location and sky conditions are important data that structure the simulation algorithm (Haqparast and Ahmadkhani Maleki, 2014). The choice of location for simulation as mentioned before is in the UAE, and the time for gauging the values required will rely on the academic calendar or the ministry of education; to reach to the highest level of accuracy and to make results more reliable. Validation process will be conducted with respect to many input information which will be demonstrated in detail in chapter 4.

3.7 Research limitations

Ministry schools are particularly the chosen types for this study, and the results expected to be obtained should be generalized for designers and decision makers to utilize this knowledge as a sustainable factor and take advantage of it. Time is a factor that limits the research as it might span for a longer time than scheduled. For that, a well-studied chart for the time-line is very crucial and leads to achievable results in each stage of research. Obtaining some resources maybe difficult to get some rules and information related to lighting and to compare it with other papers to confirm bench marks about illuminance and glare ranges according to human comfort. Simulation doesn’t include all natural aspects in attention like wall color, false ceiling details, noise, dust particles, human interference in the classroom, CFD and air exchange between outdoor and indoor. However, it’s not considered as a negative point because the focus in this research is mainly on the daylighting and the conduction will be applied specifically in the classroom.

CHAPTER 4

MODELS SETUP AND OPERATIONS CONFIGURATION

4.1 Introduction

The main motivation in this research is highly focusing on assessing ministry school buildings envelopes and to see that influence on daylighting and energy performance at the classroom. As mentioned before, computer simulation will be the basic methodology to assess the models and produce data and results to be analyzed and discussed, and eventually a closure with recommendations will conclude the paper for this subject of investigation. To clarify the considered research factors, they will be indicated below according to the researcher predictions and classification in terms of its priority in the evaluation scenario. That will guarantee achieving accurate and valid results according to each stage requirements.

4.2 Research Parameters

Of all the parameters that are considered in models, none of them will be more important than transparency and accuracy in transforming the given information in the modeling software. Simulation is based on the model location data, building construction materials, data for thermal profiles and the working hours record are all important to prepare a precise model that can be reliable and results would be appreciated. That will help in building the research on a solid framework to obtain valid outcomes that can be used for comparison purposes.

4.2.1 Assigning Weather Data

The entire modeling in this research will be located in Dubai, UAE where the weather in this region is hot arid at summer season and it's considered a moderate fair cold in the winter time. There is a remarkable quantity of dust that affects all ranges in the UAE, and high humidity levels; especially in the coastal districts of the emirates (Al-Sallal, 2010). All buildings are mainly erected on flat lands of the UAE, and mostly there are no remarkable height differences between the plots. For that, natural and man-made factors should be well thought of due to their impact on design process. The research case study will be for the dominant models ministry schools in the UAE where the sky model is CIE clear sky. Illuminance sittings are on the plane Horizontal. Calculation settings are based on daylighting, illuminance and annual energy performance (IES).

With reference to IES weather data -which supports a wide range of countries and cities weather information around the world- Dubai information are attained from the ASHRAE weather database. Simulation weather file was downloaded right away from the energyplus website for free -(https://energyplus.net)- as an IWEC file and named in the software as (AbuDhabiIWEC.fwt) in IES. And as shown in figure (4), modeling location is selected in Dubai Intl Airport, UAE (long: 25.25N, lat: 55.33E) while the Altitude is 5.0m above sea level, round reflectance is 0.2 and the time zone after GMT is 4 hours. At the summer solstice, sun rises at 05:33 and sets at 19:07 –which is around 13.5 hours of sunlight- and the winter solstice shows that 07:05 is the sunrise timing and 17:31 is the set of sun, and it means that the sun stays 10.5 hours in winter, and variation between summer and winter sun is 3 hours, and Dubai will have nearly contestant sunlight along the year with its clear sky (IES 2015).

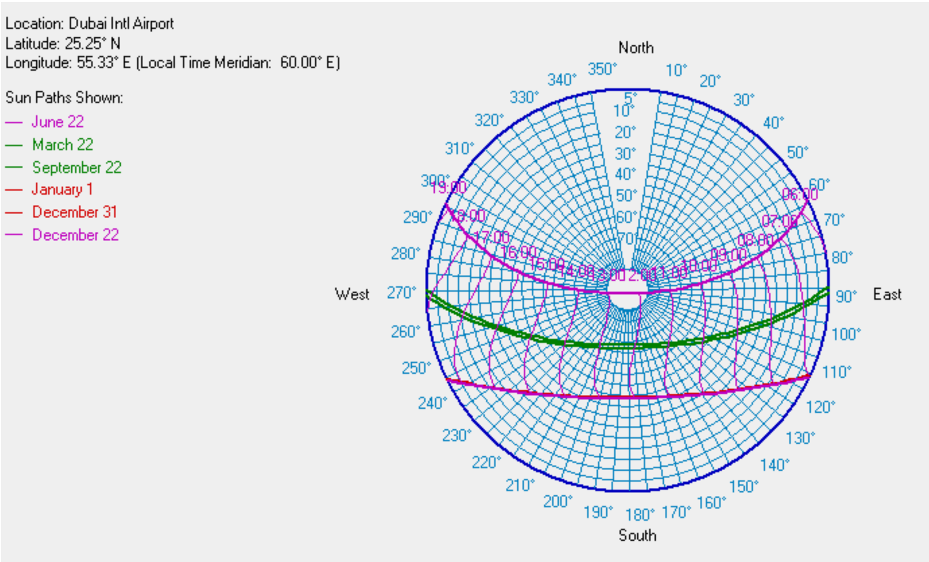


Figure (4.1) Sun path diagram for the Emirate of Dubai (IES)

4.2.2 About School practices

The school has a strong bond with students and teachers who get used to their surrounding features and try to familiarize themselves while using the space to be more adaptable. There are important factors that control the classroom performance such as daylighting, orientation, building construction materials, greenery, ventilation, acoustics and others which influence users' performance at classrooms according to the final combination of these factors. This research will base its study on IES software which offers proper and fairly enough data which are required to diagnose the building performance. Some variables at classrooms were excluded in the setup such as people and miscellaneous in the internal gain; and that will keep results focused on the considered values of lighting and electricity.

4.2.3 Orientation of the Building

Most schools –more explicitly ministry ones- in the UAE are located in rural areas, and others are moved out of the city centre; to avoid traffic jams at the daily journey while going back and forth to school. The orientation of these buildings does not follow a based code, but according to the given plot for construction, and that is noticed in buildings which don't follow a certain rhythm of orientation but consistent with the urban district and distribution.

Some schools have an optimum orientation –which was not intentionally done, but as a result of plot location and angle of alignment with the street- and others may vary to have the worst daylighting orientation which disturbs students at classrooms by glare and high illumination.

4.2.4 Selected Schools

There are 3 models which have been chosen to represent the case studies of the ministry schools according to their period of construction, form and difference in shape.

Each one of these schools is introduced below briefly to cover its basic geometrical details that will illustrate more the style of each classroom and its envelope characteristics.

KAT

Khatib & Alami is the prototype school which was designed in 1974, and it's abbreviated as KAT to be used in discussion. It was designed and approved by the ministry of education as G+ 1 floor. KAT was designed in the early stage of the united Emirates developments; and for that, it was repeatedly constructed for more than 85 prototypes as a dominant design at that time (MOE). This big number of construction is considerable and highlights an importance of the design and gives a prior validity to choose this school as a case study. So as the other chosen models of 586 and 596, they were built in various Emirates and the design was consistently stable for a significant period of time. In this design, corridors connect the grid of the distributed masses to row system, and all classes are oriented toward the same direction. As shown in figure (4.2), the 87x67 meters building mass has a central courtyard which is designed for the daily morning commencement, and students gather at break time to spend a good period while having breakfast. Other 5 courtyards where designed to provide lighting for classrooms across the whole days of the year. All classrooms are oriented towards one direction which helps a better school position with sun, and classes will be arranged to the best orientation. Evaluating the optimum orientation for classroom is another part of interest to choose these models with respect to the distribution of Kat –as all classess are one direction oriented- as well as 586 and 596 which have two oppostie distributed classes around the courtyard as explained later.

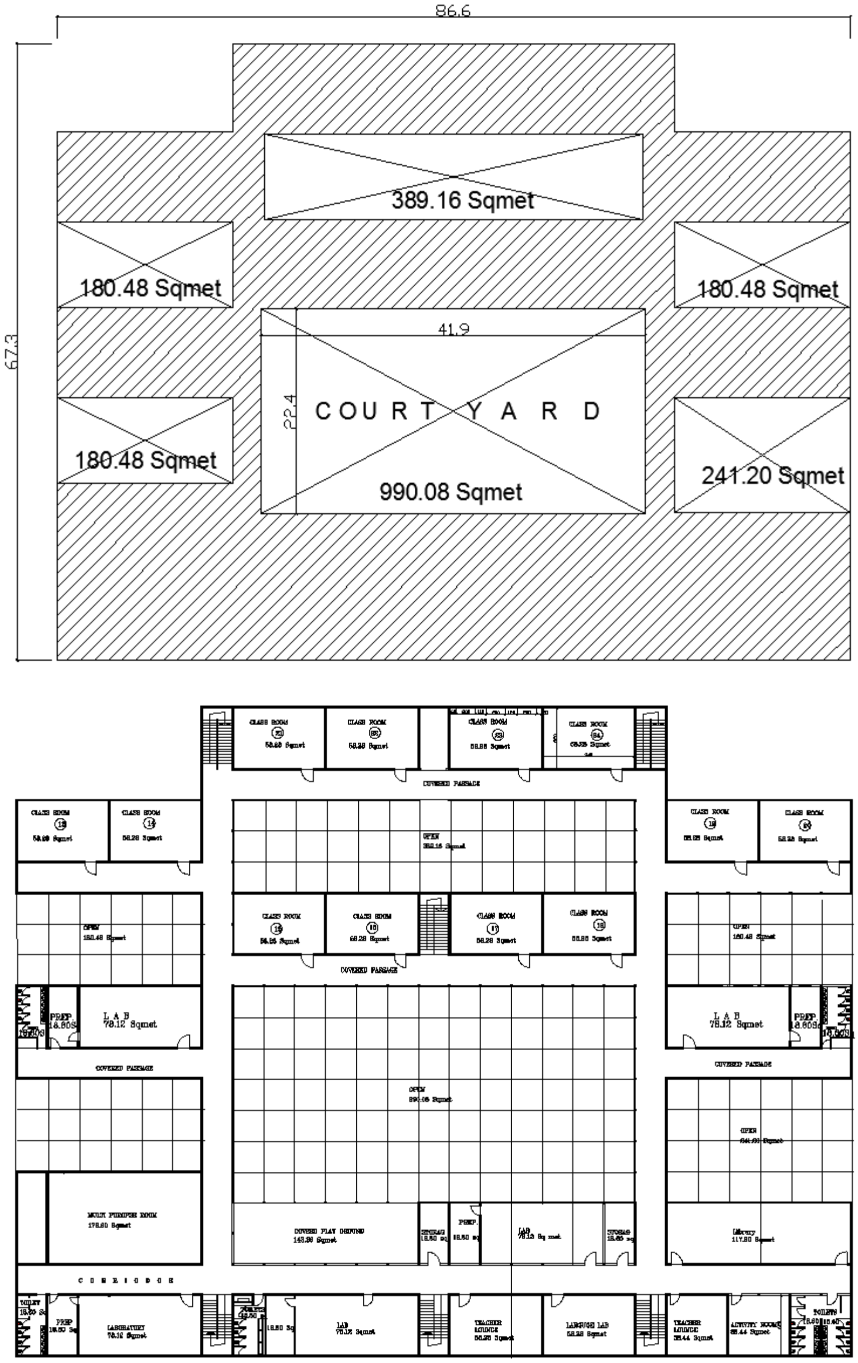


Figure (4.2) KAT school site plan and ground floor plan (MOE)

586 model

Second school is named as 586 which was initially constructed in 1988. Figure (4.3) shows that it's basically a cube shaped mass with a main courtyard in the middle for the morning gathering. The 2 courtyards are located on the upper sides to provide daylighting for the lower classroom.

First floor is constructed on the 1/3 area of the ground floor plan for extra classes for different activities. This 96x100 meters school has its classrooms on both sides –right and left- of the main mass where daylighting is variant in each side along the day time especially that glazing and envelope are treated the same in both side. This design was constructed and had about 40 models which were spread around the UAE.

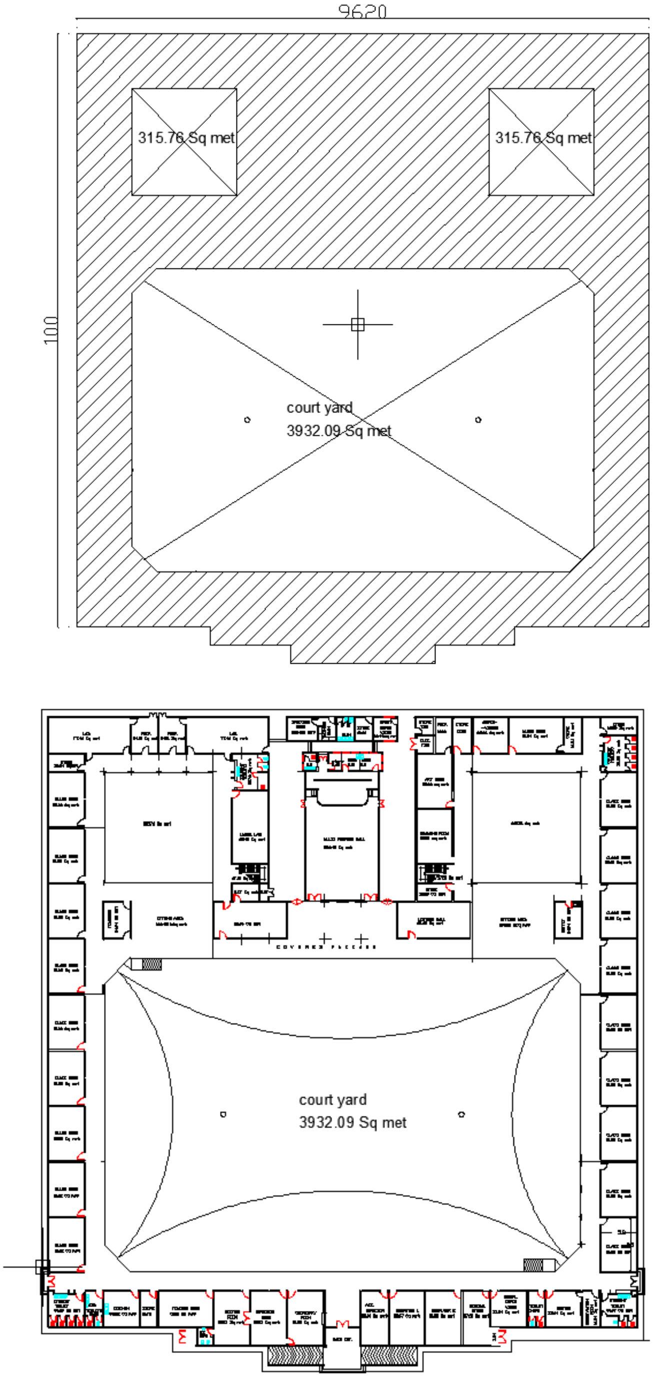


Figure (4.3) 586 school model site plan and ground floor plan (MOE)

596 model

Third school model started its prototype in 1997 as the first construction. It’s an improved version of 586 but different in the envelope dimension where this model is 79x78.6 meters as clarified in figure (4.4), yet almost about 10 models were erected. Similarly here, classrooms have both directions distribution which is facing the same issue of having fluctuation in daylighting in each side of the school. In 596, two extra open areas –or court- were added to provide daylight for extra rooms and facilities.

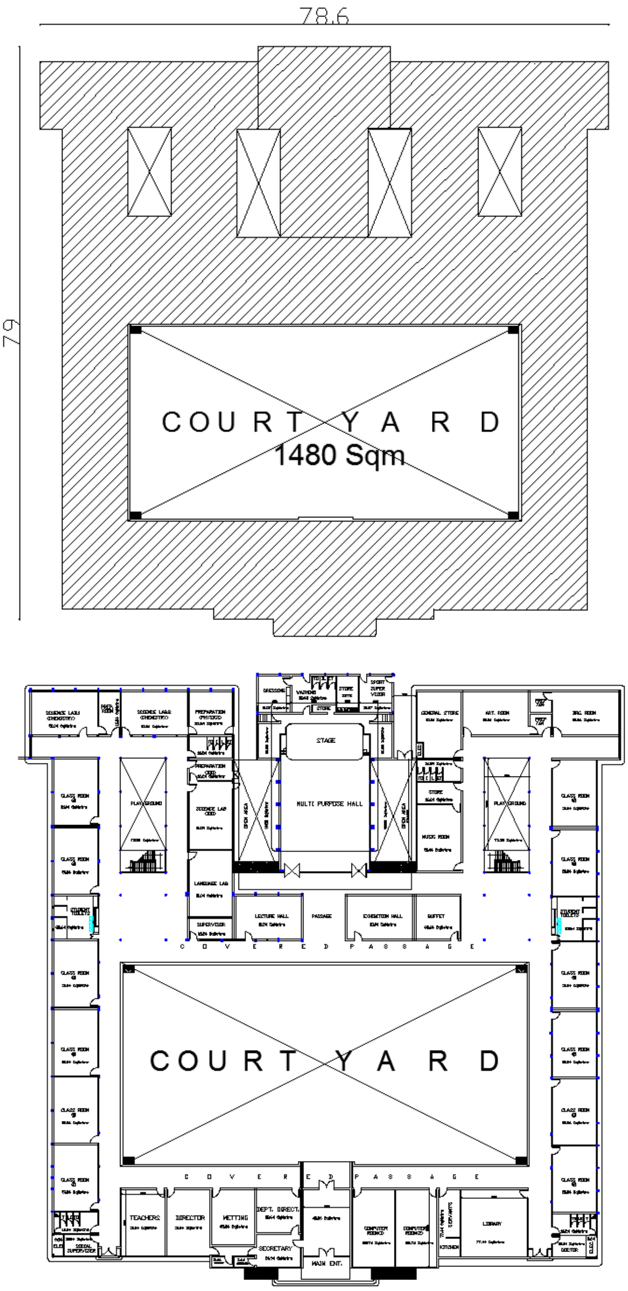


Figure (4.4) 586 school model site plan and ground floor plan (MOE)

As the selected schools were demonstrated, one classroom will be modeled to present each school's condition, later a simulation study will focus on illuminance, daylighting, energy and consumptions with respect to all cardinal directions. After that, a comparison will take place between the three models; to select the best one which has the optimum impact on daylight and energy. Eventually, an improvement study will concentrate on the one which attempts to be healthy and beneficial in terms of daylighting quality and energy saving potentials.

4.3 Models description in brief

As mentioned before, there are main models of 3 schools which were chosen to represent their period of design and classroom proportions and envelope variation. Each of these schools has a classroom space which is modeled as per the municipality drawings, and the same classroom will be oriented to the main four directions; to imitate the case of having the school in all cardinal directions. Classrooms were initially modeled and tested as follow:

Table (4.1) Detail for classroom models that will be assessed using IES

School model / Room orientation	KAT	586	596
North	✔	✔	✔
East	✔	✔	✔
West	✔	✔	✔
South	✔	✔	✔
Sum	**4**	**4**	**4**
Total	**12 models**		

The 12 models of the classrooms were simulated with reference to the 2 illustrated profiles previously –with and without dimming sensor- and that is making the total of 24 models that have been simulated in the first phase of the research; to inspect the effect of daylighting on energy performance along the academic year and select the best case that has the lowest consumption between the 24 models according to the existing status of these classrooms. Accordingly, the chosen model will be the new base case to be designed and tested for solution to reduce the energy intake with respect to the best daylighting gain in the classroom, and taking into account parameters discussed in the literature review chapter.

4.3.1 Models dimensions

Drawings of schools were requested from both the ministry of education and the Ministry of Public Works (MOPW) in Dubai, and they offered plans and sections and construction details for flooring, walls and roofs which were used in modeling the schools as mentioned above, and afterwards, models were prepared to be analyzed in IES in the simulation phase. The three models of schools KAT, 586 and 596 are illustrated in Table (4.2) with all dimensions required to draw them accurately, and the work plane height is fixed for all of them on 0.75 meters above the flooring level.

Table (4.2) School models and the classroom dimensions used in IES

Room specs / School model	KAT	586	596
Length (m)	9.4	8.8	8.8
Width (m)	6.2	5.8	5.8
Height (m)	3.4	3.3	3
Area (m^2)	58	51	51
Volume (m^3)	198	168	153
Work plane desk (m)	0.75	0.75	0.75

4.4 Validation of the Models

It was illustrated before when IES software was verified and showed that its accuracy is convenient and many researchers mentioned that they referred to the results obtained by the IES which are reasonable and have a bench mark to state outcomes accordingly. Azhar, Brown and Sattineni (2010) debated that when a real building is simulated in IES, results of the software are fair to compare with the real building records, and they are assumed to be the same match. Principally, all models input data, templates, calendars, profiles and details were applied using IES, and for that, validations and model comparison methods will be typically calibrated according to the technical aspects which refer to software testing system. Model optimization shall be done in the second phase where some enhancement proposals will be applied on the nominated best base case from the first phase. After that, verification of the results will show the accuracy when compared to some well- targeted experiments; especially that these trials were done by academics and professional researchers who investigated this division of concern a plenty of studies. Discriminant analysis is going to take place in the final part of chapter five, and that will help testing data and the performance of the models in terms of their response to daylighting and electrical consumption will be compared, and models statistical outputs will have assumptions with respect to the schools regulations, local codes and international recommendations related to conduct and respond to the research concerns.

The 3d model in figure (4.5) visualization shows that KAT has a unique opening on the upper side above the door of the classroom –having 3 openings 0.8x2.6m- which functions like a clearstory; for a balanced distribution as an indirect source of daylight. The other side of the classroom is shown in the plan in figure (4.6) has 4 windows with different width size where the window sill start from 0.77m and their height is 1.4m.

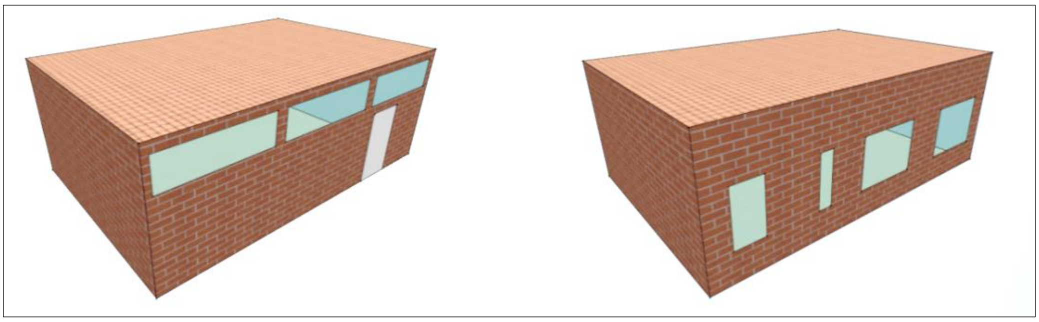


Figure (4.5) KAT classroom model showing envelope openings (IES)

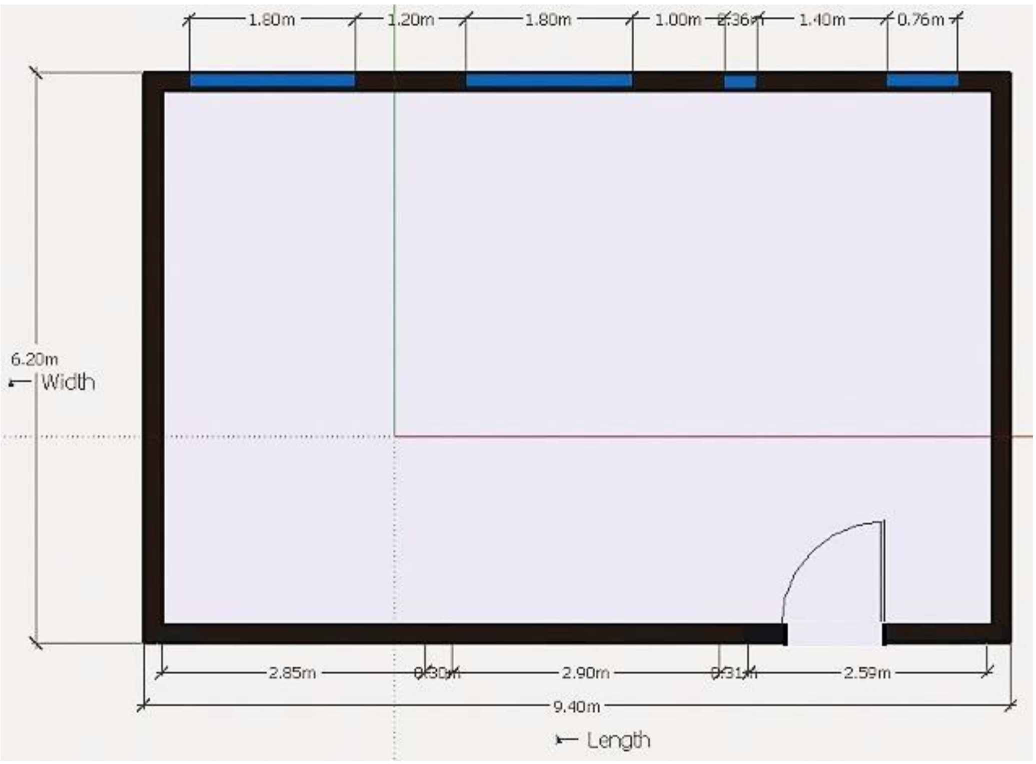


Figure (4.6) KAT classroom model plan view with dimensions

Figure (4.7) shows that the main envelope of 586 model has 5 windows ordered in a row –width is 1.3m and height is 1.25m- and they are raised from the floor level by 0.85m. In this prototype, the clear-story like windows are located at the other side of the classroom but divided to 6 windows with a dimension of 0.6h x 0.9d and dropped from the roof by 0.4m.

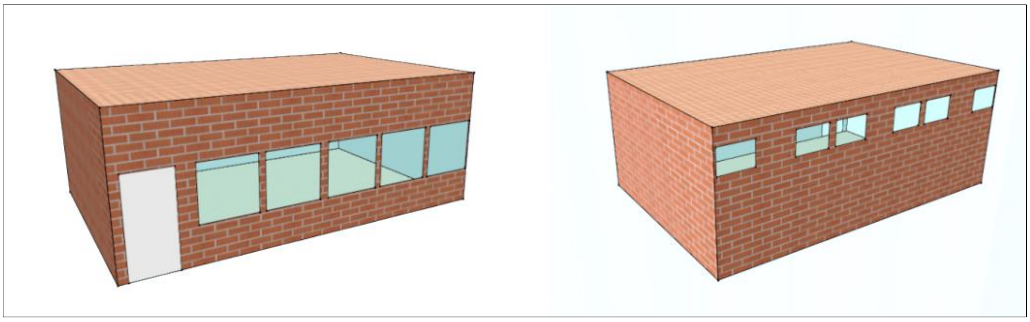


Figure (4.7) 586 classroom model showing envelope openings (IES)

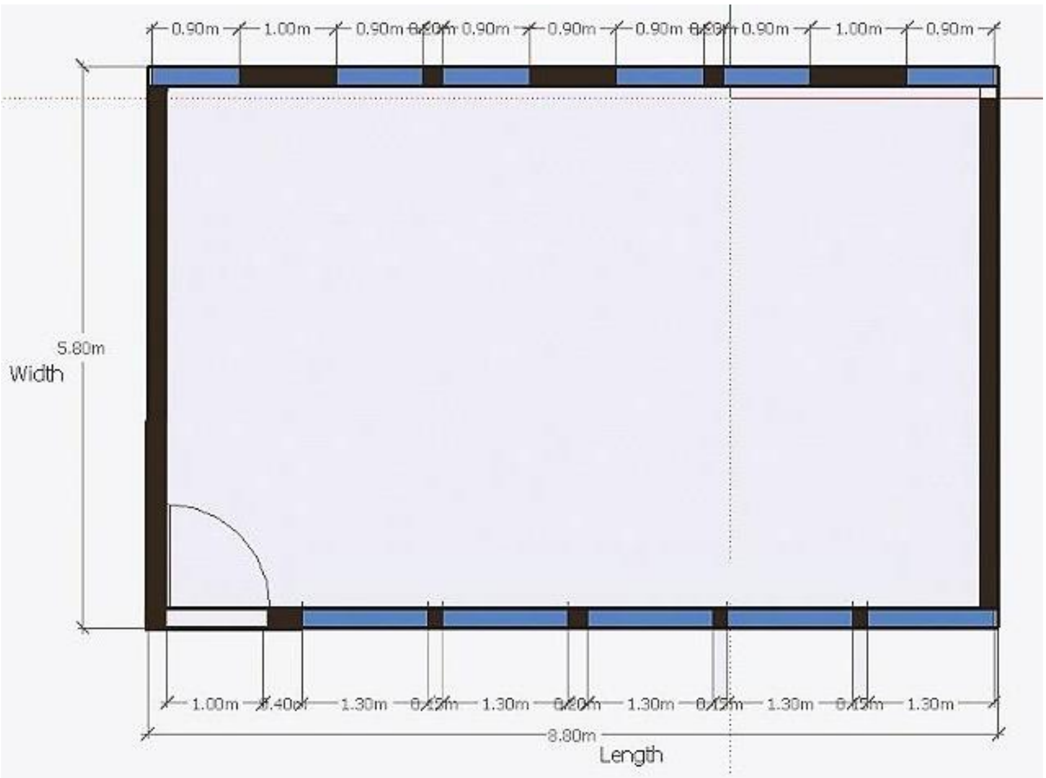


Figure (4.8) 586 classroom model plan view with dimensions

This model has the same dimensions of the 586 volume but the height is changed. The special component in this design is the glazing in the front side of the classroom. It has two big windows – 1.25 height x 2.75 m length- to deliver an impression of continuous glazing façade which keeps a higher chance of visual interaction between the outdoors and indoor environment. Same windows design is applied at the back side of the classroom.

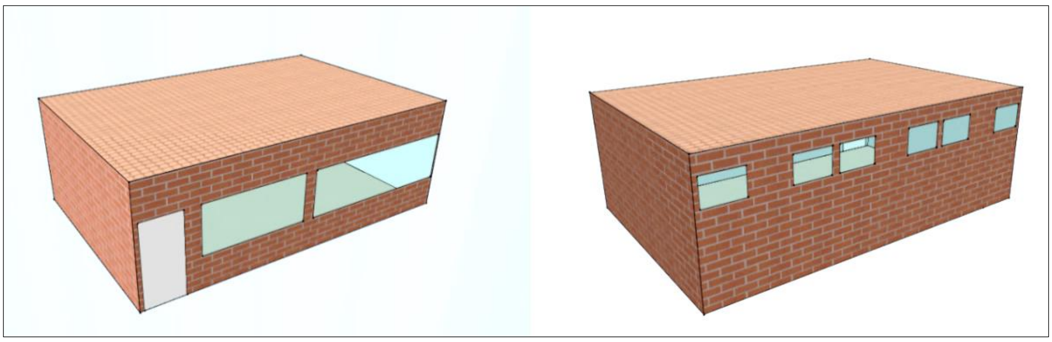


Figure (4.9) 596 classroom model showing envelope openings (IES)

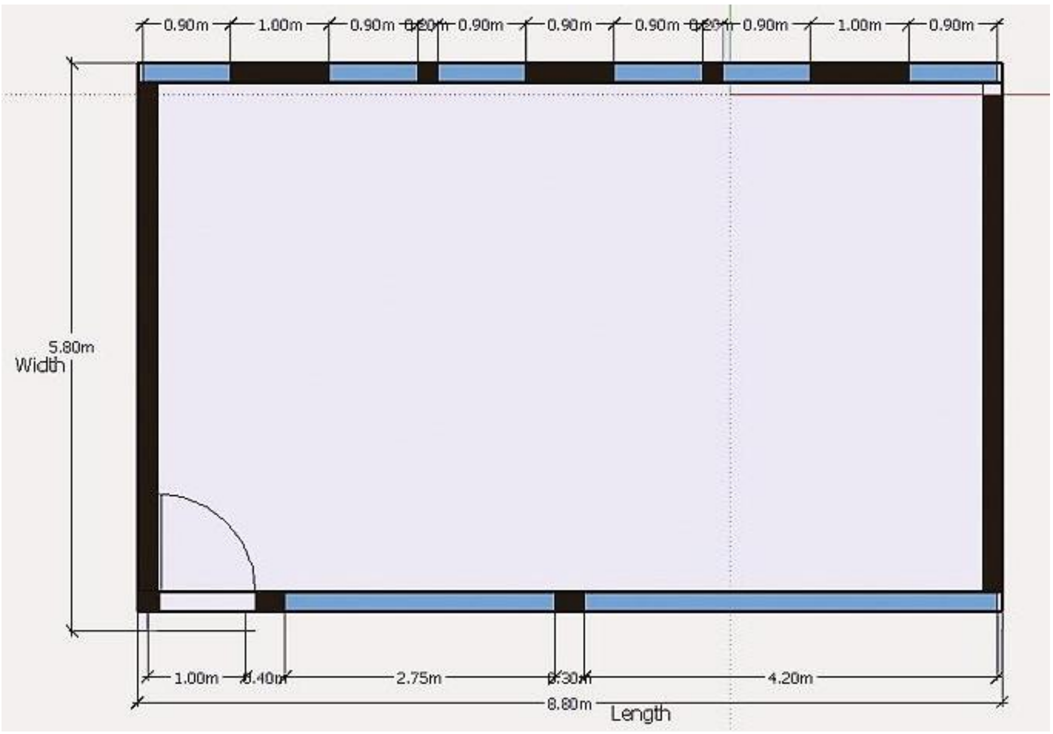


Figure (4.10) 596 classroom model plan view with dimensions

4.5 Profile settings

Modeling in IES should have a set up for many profiles for each project such as working hours timing, thermal profile, dimming profile –in case of lighting sensor- and they can be created either by adding specific values related to the building database information, or by adding formulas which are given for each model. Cooling profiles are based also on the school timing, regardless class heating which is not required in models location. This study focused on classrooms of the UAE ministry schools where an official calendar is issued online at the ministry of education of the UAE and distributed to ministry and private schools and they apply it on the academic year.

4.5.1 Daily profile

There are two daily occupancy daily profiles which were applied along the simulation process of all models.

Both of them referred to the working hours of students at schools, and they considered that the working day starts at 07:00 and ends by 14:30 when students and teachers dismiss. The main modification in the second profile was by conducting a dimming profile for the daylighting, and that sensor profile will be illustrated later in this page.

The first profile was called (School Original Daily profile) as shown in figure (4.11) and it's the original case of working hours at schools. The profile runs continuously from 06:00 to 14:30, and that keeps the thermal condition profile working consistently unless a human interferes to stop either the AC conditioner or the lights in the classroom.

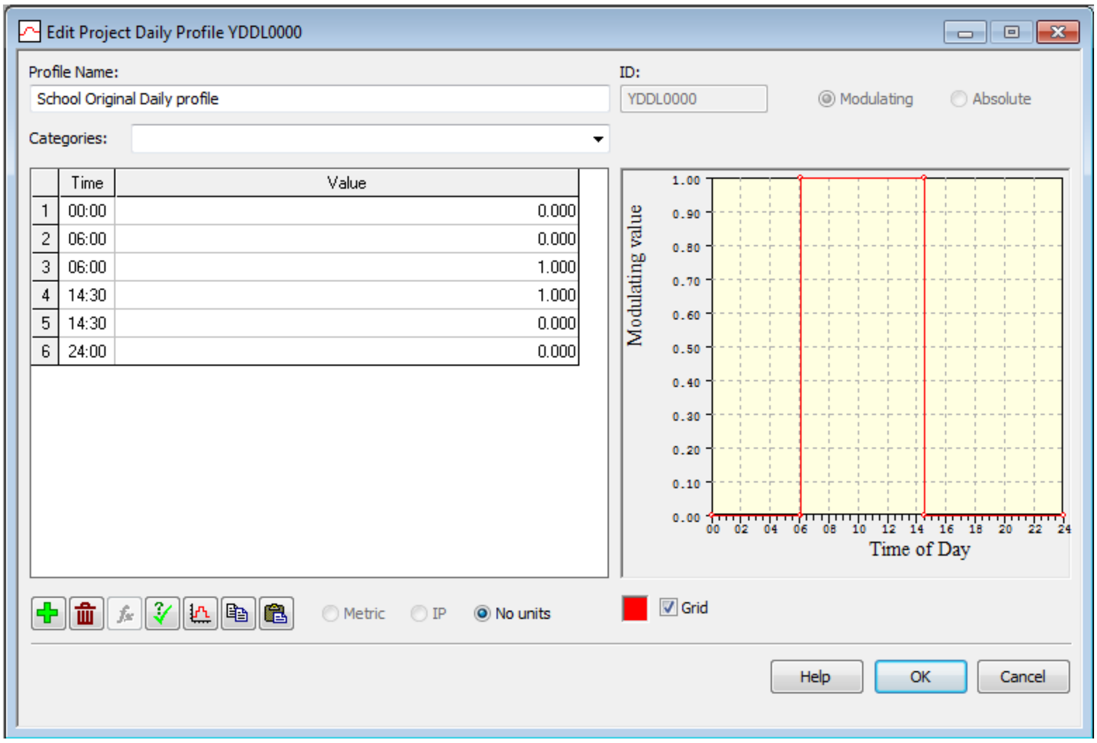


Figure (4.11) Daily profile for school occupants (IES)

The second profile applied the same timing; however it has more control on the artificial lighting system at the classroom. Integrating the sensor as an intelligent system can detect the lux level of natural daylighting in the classroom. If the value gets less than 500 lux, dimmers will run the artificial lights; to keep lighting final outcome consistent and uniform in the classroom along the daytime. For that, figure (4.12) shows the formula used in the daily profile, and was created and modulated in the following mode: ramp (e1,0,1,500,0). It was located on the working plane looking upwards. This formula means that the profile will fall from one at zero illuminance to zero at illuminance 500 lux in the room, and it persists stable and consistent at this certain rate. And this means that the light will not be dimmed as long as there is an equals or higher level of daylighting than 500 lux, and that will be the responsibility of the sensor to keep this level of light constant.

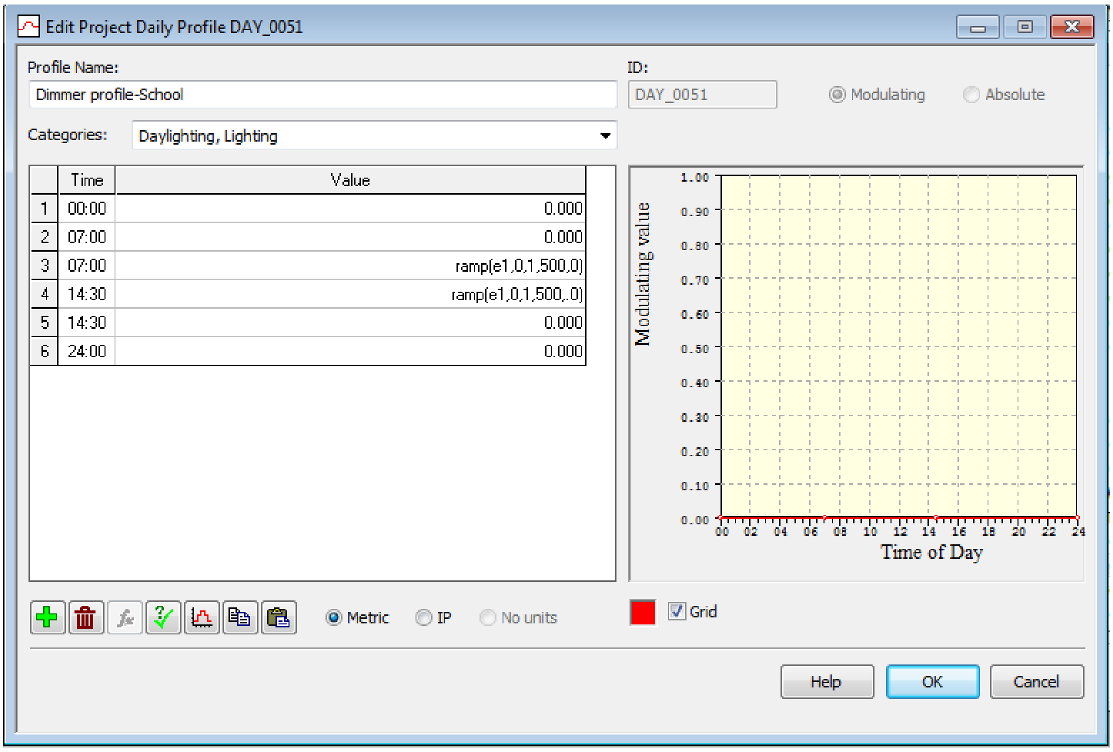


Figure (4.12) Daily dimmer profile for school occupants with sensor (IES)

4.5.2 Weekly Profile

Schools have 5 working days a week which begins by Sunday and ends by Thursday. There is only one weekly profile which was applied on both profiles, and it was termed (School- weekly profile). Figure (4.13) indicates that Fridays and Saturdays are always considered as holidays, in addition to that, the official vacation days are already inserted manually in the simulation calendar system with holiday name and definition, and consequently, the holidays will apply the off day accordingly.

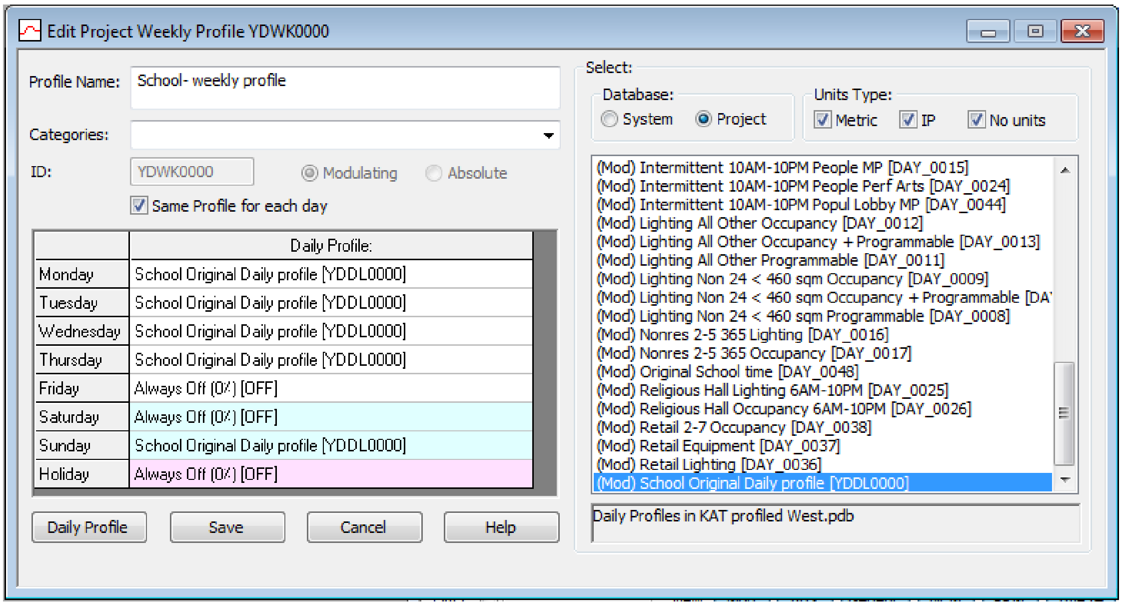


Figure (4.13) Weekly profile for school occupants (IES)

4.5.3 Annual profile

After creating the weekly profile, every month accumulate the result of its four weeks accordingly to be used for the annual profile as shown in figure (4.14). The profile name is the “Base Case- Annual Profile” is the one used across all models and scenarios. It’s essential to state that students have 3 academic semesters which are divided by vacations, and the longest is at summer when they spend July and august as an annual vacation; and afterwards they commence the new academic year. And that is already added in the holiday template in simulation calendar as mentioned before.

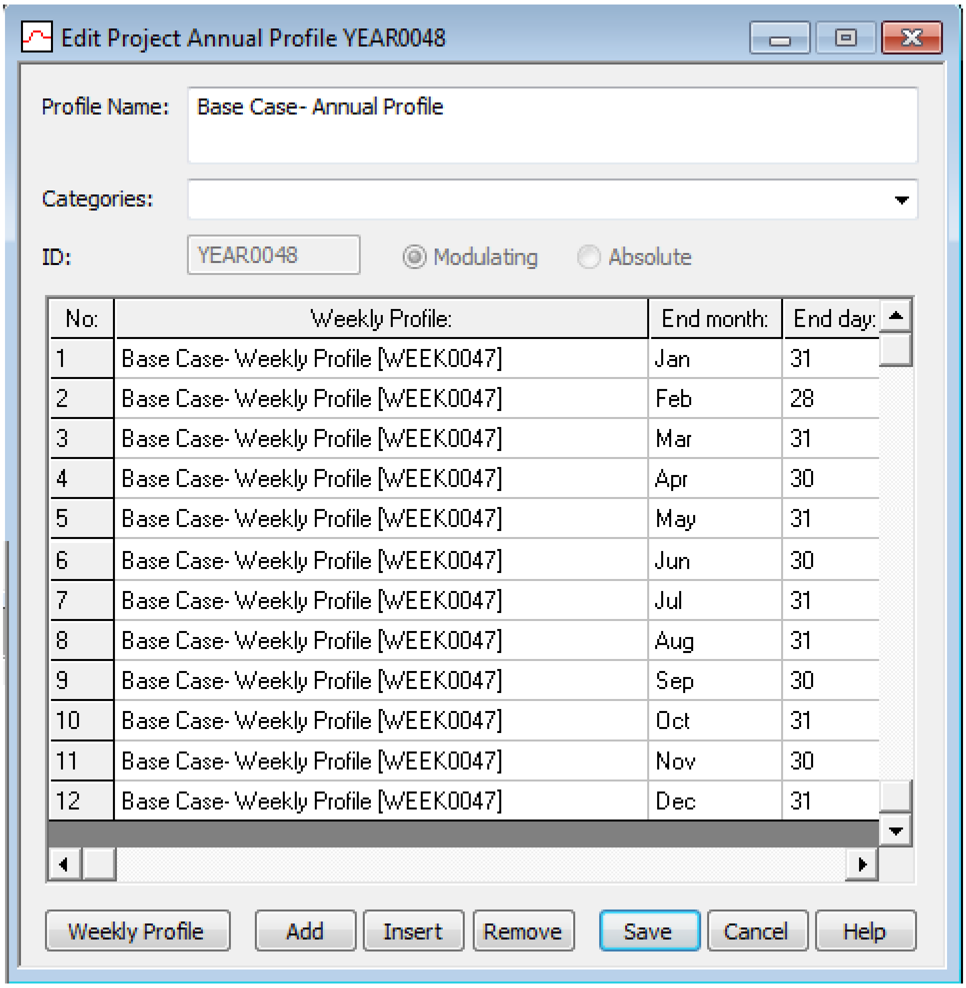


Figure (4.14) Weekly profile for school occupants (IES)

4.5.4 Simulation calendar

According to the calendar published by the ministry of education, simulation calendar holidays were added to duplicate the current academic year on the software. In figure (4.15) the yellow highlight defines holidays in the months and shows the off days like Fridays and Saturdays including all public holidays with respect to each holiday name and period in year 2015.

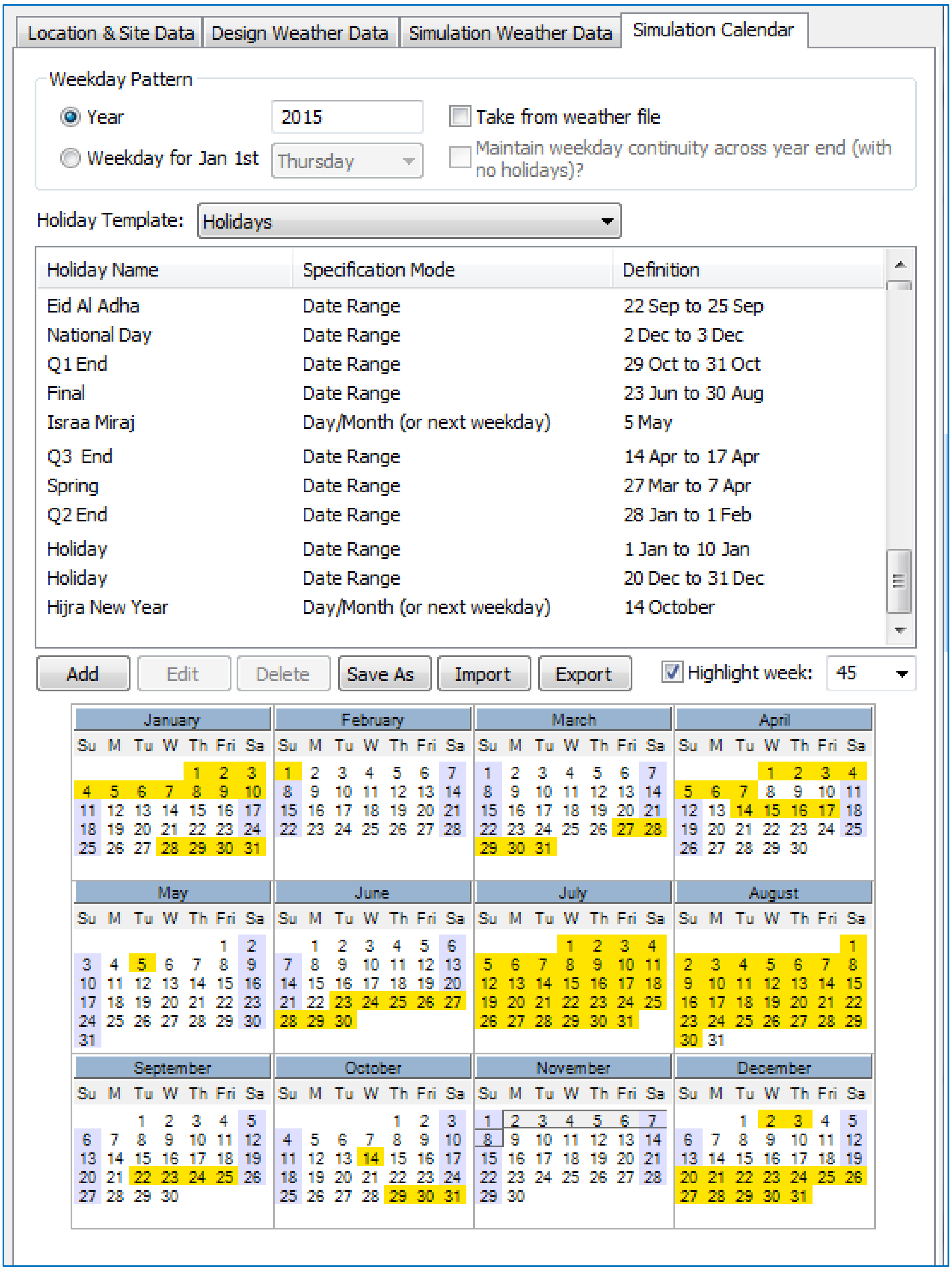


Figure (4.15) Simulation calendar as given from MOE (IES)

4.5.5 Thermal Profile

There is only one thermal template which was created for all models in simulation process and it's called (Base Case- School normal thermal). In the building regulations, the National Calculation Methodology (NCM) defines the type and activity that occurs within the building rooms, and it was assigned for the model in IES thermal conditions as (D1: Primery or Secondary school (Primary)), and the selected NCM activity was (NCM D1Edu: Teaching areas). Profile used for cooling and internal gains is (school original annual profile). For parameters in internal gains, people occupancy gain reference is zero, and fluorescent light use the default variation profile, and the dimming profile is used once in the base case, and another time for the dimming sensor system.

4.5.6 Construction Template

With reference to Dubai Municipality regulations and circulars regarding the materials and codes of building, a construction database was prepared for the main 4 building elements which are the walls, flooring, glazing and roofing materials. IES classification system in building construction materials according to their type and finishing materials facilitated for the author to create all layers of construction according to the U-Values, thickness and materials technical details; to match those which are required in reality for each element in modeling.

The first phase of simulation will have 3 main different project construction templates according to each school workshop drawings and specifications. After that, the best efficient model shall be selected. Later on, in the second phase only one part of simulation will choose different materials for the 4 main building elements to check which element can reduce a significant electrical and lighting values –where the variation will be taken from the updated codes of DM, Estidama P1 and P2- then the rest of models will base on the same previous best base case construction template to apply various envelope criteria for evaluation.

4.6 Structure of analysis

Scenarios will have 2 main configurations where the 12 models in the first batch will not have dimming profile; because of the real existing cases. The next batch of 12 models will be fitted with sensors and dimming profile to assess the impact of saving and performance on the same rooms. Out of these 24 models, a particular model will be selected according to the best performance in energy consumption and lighting sufficiency in the classroom. KAT, 586 and 596 will be analyzed according to the configuration outlined and mentioned earlier with respect to the daylighting control through glazing, orientation of the classrooms and the energy amounts consumed annually.

4.6.1 Existing Schools (Constructions Templates)

KAT template

Since 1974, students occupied this design model and experienced the way it was designed without having a competent design that can provide a comparison platform. Yet, it was built according to the recommended materials and design criteria at that period. Glazing is single in KAT as shown in figure (4.16), and it's a clear transparent float type with 6mm thickness.

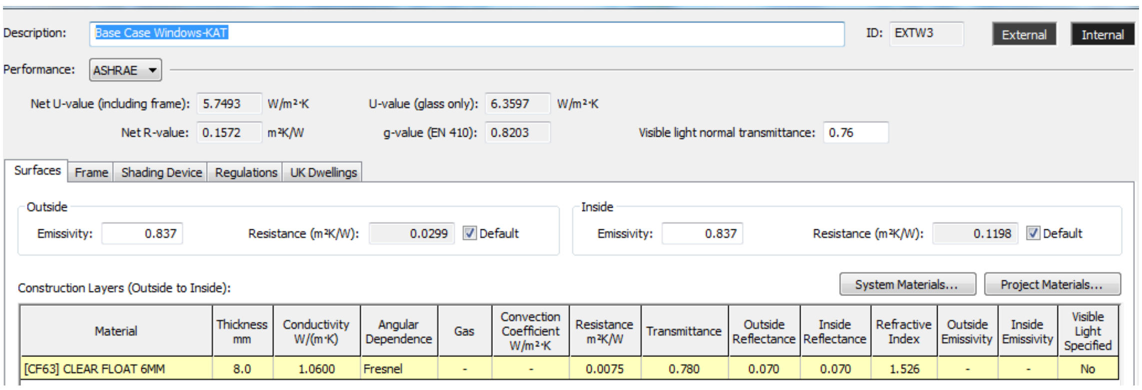
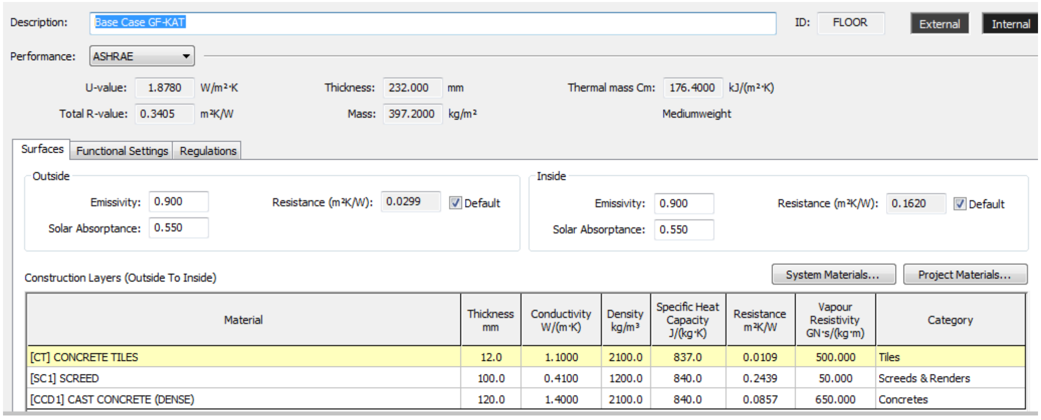


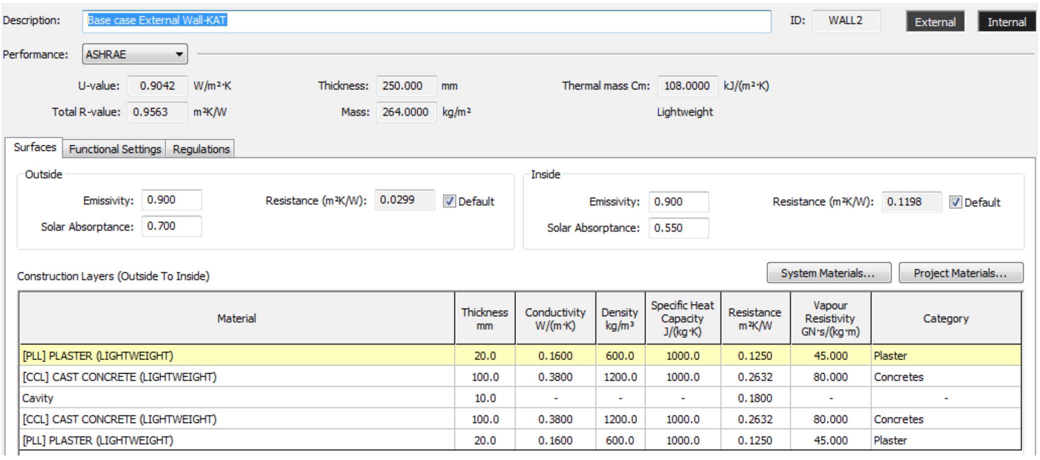
Figure (4.16) KAT Glazed External Windows (IES)

As follow, the other components of KAT classroom materials are shown in figure (4.17) for flooring, (4.18) for walls and (4.19) for the roof construction laying order.



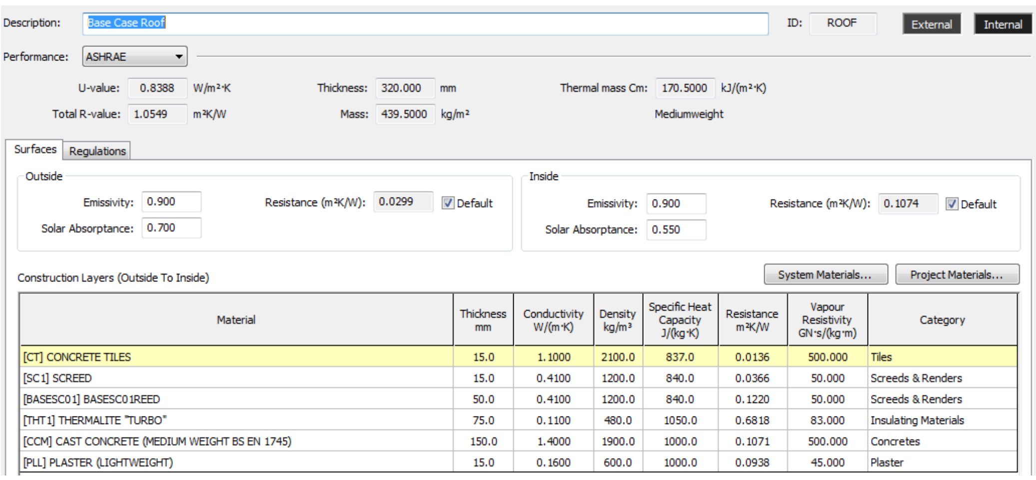
Material	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[CT] CONCRETE TILES	12.0	1.1000	2100.0	837.0	0.0109	500.000	Tiles
[SC1] SCREED	100.0	0.4100	1200.0	840.0	0.2439	50.000	Screeds & Renders
[CCD1] CAST CONCRETE (DENSE)	120.0	1.4000	2100.0	840.0	0.0857	650.000	Concretes

Figure (4.17) KAT Ground Floor construction layers (IES)



Material	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[PLL] PLASTER (LIGHTWEIGHT)	20.0	0.1600	600.0	1000.0	0.1250	45.000	Plaster
[CCL] CAST CONCRETE (LIGHTWEIGHT)	100.0	0.3800	1200.0	1000.0	0.2632	80.000	Concretes
Cavity	10.0	-	-	-	0.1800	-	-
[CCL] CAST CONCRETE (LIGHTWEIGHT)	100.0	0.3800	1200.0	1000.0	0.2632	80.000	Concretes
[PLL] PLASTER (LIGHTWEIGHT)	20.0	0.1600	600.0	1000.0	0.1250	45.000	Plaster

Figure (4.18) KAT External Wall construction layers (IES)

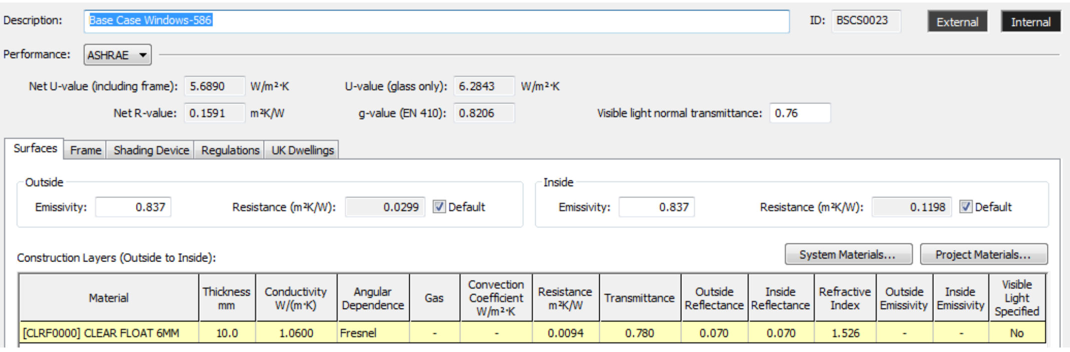


Material	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[CT] CONCRETE TILES	15.0	1.1000	2100.0	837.0	0.0136	500.000	Tiles
[SC1] SCREED	15.0	0.4100	1200.0	840.0	0.0366	50.000	Screeds & Renders
[BASESC01] BASESC01REED	50.0	0.4100	1200.0	840.0	0.1220	50.000	Screeds & Renders
[THT1] THERMALITE "TURBO"	75.0	0.1100	480.0	1050.0	0.6818	83.000	Insulating Materials
[CCM] CAST CONCRETE (MEDIUM WEIGHT BS EN 1745)	150.0	1.4000	1900.0	1000.0	0.1071	500.000	Concretes
[PLL] PLASTER (LIGHTWEIGHT)	15.0	0.1600	600.0	1000.0	0.0938	45.000	Plaster

Figure (4.19) KAT Roof construction layers (IES)

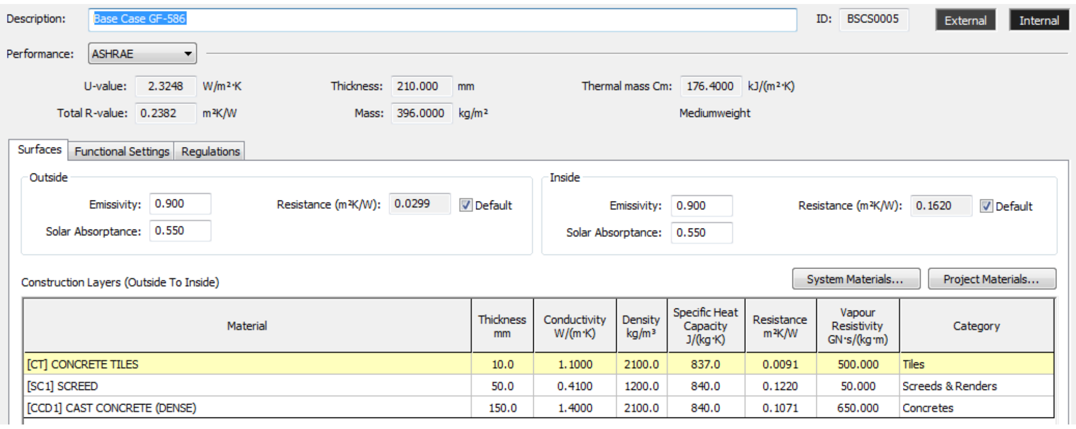
586 template

This school model was initially erected in the beginning of 1988 which is after 14 years of KAT prototype production. Its shape was different and the proportions of the classroom were also changed as described earlier in details. Glazing was still single while the other components materials were changed as shown in the figures (4.20) – (4.23) and it shows some variation in the U-Value between KAT and 586 due to the changes of materials and thicknesses.



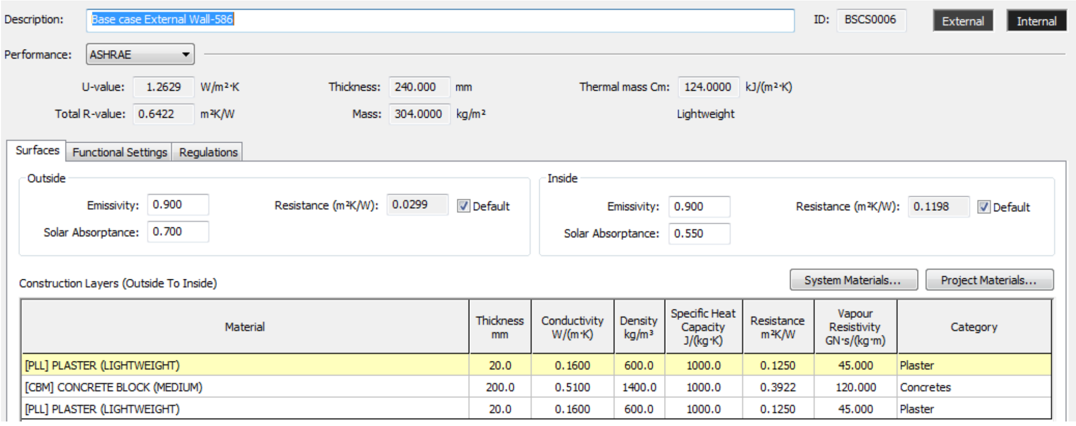
Material	Thickness mm	Conductivity W/(m·K)	Angular Dependence	Gas	Convection Coefficient W/m²·K	Resistance m²K/W	Transmittance	Outside Reflectance	Inside Reflectance	Refractive Index	Outside Emissivity	Inside Emissivity	Visible Light Specified
[CLRF0000] CLEAR FLOAT 6MM	10.0	1.0600	Fresnel	-	-	0.0094	0.780	0.070	0.070	1.526	-	-	No

Figure (4.20) 586 Glazed External Windows (IES)



Material	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[CT] CONCRETE TILES	10.0	1.1000	2100.0	837.0	0.0091	500.000	Tiles
[SC1] SCREED	50.0	0.4100	1200.0	840.0	0.1220	50.000	Screeds & Renders
[CCD1] CAST CONCRETE (DENSE)	150.0	1.4000	2100.0	840.0	0.1071	650.000	Concretes

Figure (4.21) 586 Ground Floor construction layers (IES)



Description: Base case External Wall-586 ID: BSCS0006 External Internal

Performance: ASHRAE

U-value: 1.2629 W/m²·K Thickness: 240.000 mm Thermal mass Cm: 124.0000 kJ/(m²·K)

Total R-value: 0.6422 m²K/W Mass: 304.0000 kg/m² Lightweight

Surfaces | Functional Settings | Regulations

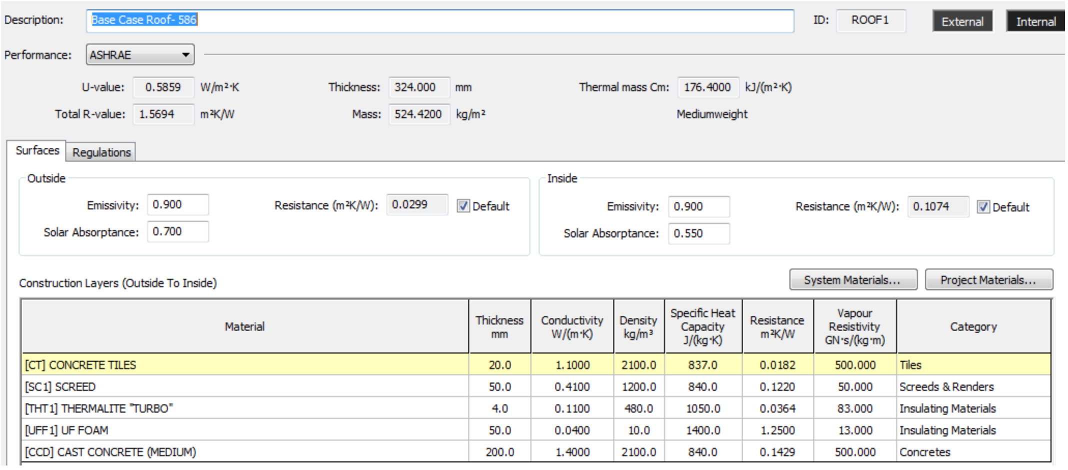
Outside: Emissivity: 0.900 Solar Absorptance: 0.700 Resistance (m²K/W): 0.0299 Default

Inside: Emissivity: 0.900 Solar Absorptance: 0.550 Resistance (m²K/W): 0.1198 Default

Construction Layers (Outside To Inside) System Materials... Project Materials...

Material	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[PLL] PLASTER (LIGHTWEIGHT)	20.0	0.1600	600.0	1000.0	0.1250	45.000	Plaster
[CBM] CONCRETE BLOCK (MEDIUM)	200.0	0.5100	1400.0	1000.0	0.3922	120.000	Concretes
[PLL] PLASTER (LIGHTWEIGHT)	20.0	0.1600	600.0	1000.0	0.1250	45.000	Plaster

Figure (4.22) 586 External Wall construction layers (IES)



Description: Base Case Roof- 586 ID: ROOF1 External Internal

Performance: ASHRAE

U-value: 0.5859 W/m²·K Thickness: 324.000 mm Thermal mass Cm: 176.4000 kJ/(m²·K)

Total R-value: 1.5694 m²K/W Mass: 524.4200 kg/m² Mediumweight

Surfaces | Regulations

Outside: Emissivity: 0.900 Solar Absorptance: 0.700 Resistance (m²K/W): 0.0299 Default

Inside: Emissivity: 0.900 Solar Absorptance: 0.550 Resistance (m²K/W): 0.1074 Default

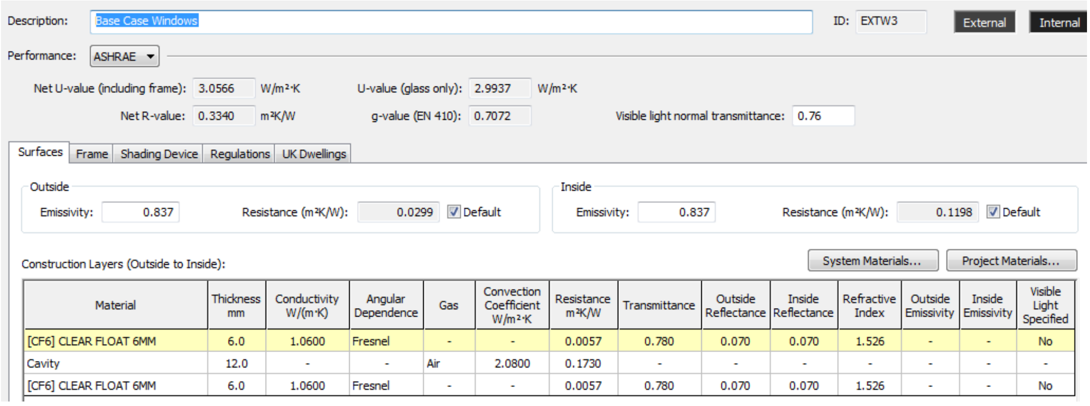
Construction Layers (Outside To Inside) System Materials... Project Materials...

Material	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[CT] CONCRETE TILES	20.0	1.1000	2100.0	837.0	0.0182	500.000	Tiles
[SC1] SCREED	50.0	0.4100	1200.0	840.0	0.1220	50.000	Screeds & Renders
[THT1] THERMALITE "TURBO"	4.0	0.1100	480.0	1050.0	0.0364	83.000	Insulating Materials
[UFF1] UF FOAM	50.0	0.0400	10.0	1400.0	1.2500	13.000	Insulating Materials
[CCD] CAST CONCRETE (MEDIUM)	200.0	1.4000	2100.0	840.0	0.1429	500.000	Concretes

Figure (4.23) 586 Roof construction layers (IES)

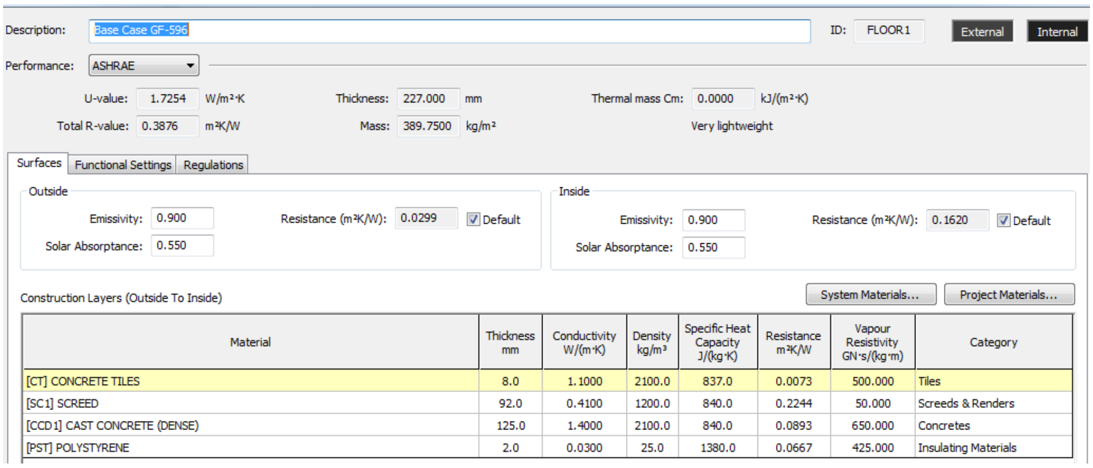
596 template

It was built first in 1997 –which is after 23 years later than KAT- and some more considerations were added in the classroom depth and corridors to provide shade. Glazing in the 596 was improved to a double glazing system to reduce heat and incident radiations as shown in figure (4.24). Ground floor materials in figure (4.25) show the reduction in the U-Value of the new layers compared to the previous two models. Figure (4.26) and (4.27) show the new updated layering system which is applied on 596 model; to reduce as much heat and electricity as possible in this new model.



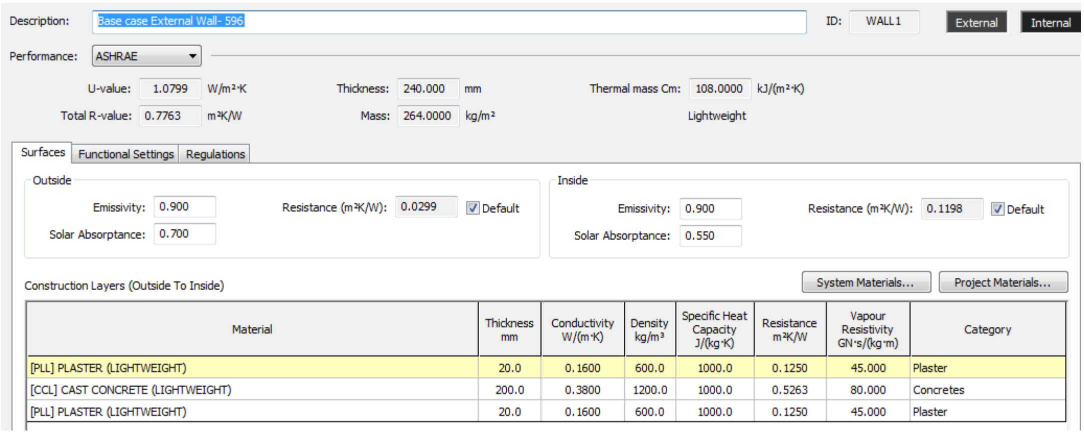
Material	Thickness mm	Conductivity W/(m·K)	Angular Dependence	Gas	Convection Coefficient W/m²·K	Resistance m²K/W	Transmittance	Outside Reflectance	Inside Reflectance	Refractive Index	Outside Emissivity	Inside Emissivity	Visible Light Specified
[CF6] CLEAR FLOAT 6MM	6.0	1.0600	Fresnel	-	-	0.0057	0.780	0.070	0.070	1.526	-	-	No
Cavity	12.0	-	-	Air	2.0800	0.1730	-	-	-	-	-	-	-
[CF6] CLEAR FLOAT 6MM	6.0	1.0600	Fresnel	-	-	0.0057	0.780	0.070	0.070	1.526	-	-	No

Figure (4.24) 596 Glazed External Windows (IES)



Material	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[CT] CONCRETE TILES	8.0	1.1000	2100.0	837.0	0.0073	500.000	Tiles
[SC1] SCREED	92.0	0.4100	1200.0	840.0	0.2244	50.000	Screeds & Renders
[CCD1] CAST CONCRETE (DENSE)	125.0	1.4000	2100.0	840.0	0.0893	650.000	Concretes
[PST] POLYSTYRENE	2.0	0.0300	25.0	1380.0	0.0667	425.000	Insulating Materials

Figure (4.25) 596 Ground Floor construction layers (IES)



Material	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[PLL] PLASTER (LIGHTWEIGHT)	20.0	0.1600	600.0	1000.0	0.1250	45.000	Plaster
[CCL] CAST CONCRETE (LIGHTWEIGHT)	200.0	0.3800	1200.0	1000.0	0.5263	80.000	Concretes
[PLL] PLASTER (LIGHTWEIGHT)	20.0	0.1600	600.0	1000.0	0.1250	45.000	Plaster

Figure (4.26) 596 External Wall construction layers (IES)

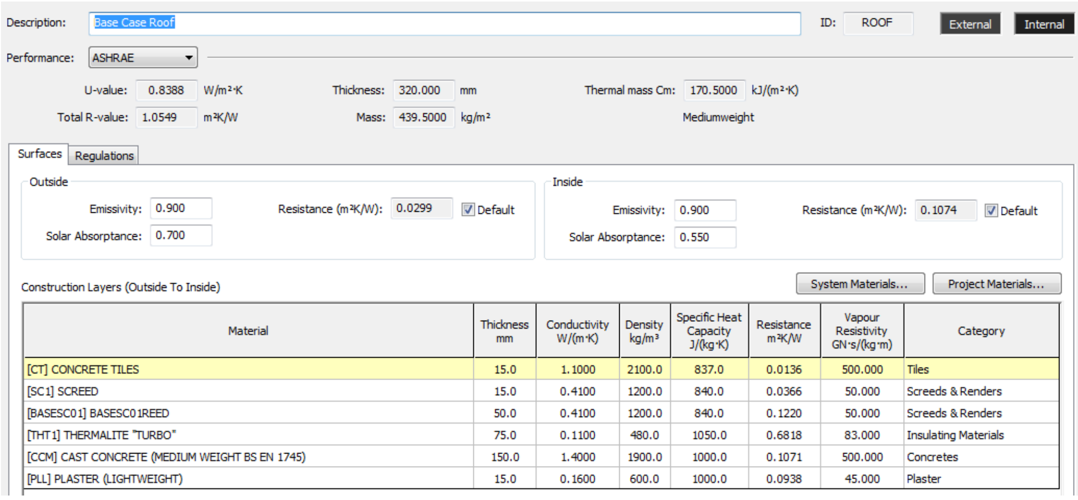


Figure (4.27) 596 Roof construction layers (IES)

The above listed materials are built with reference to the given information and drawings from both MOE and MOPW, in addition to the field measurement took place in every model of the mentioned schools to document some missing measurements. After that, all of these information were translated on drawings which were computerized using the IES software. Each component was described according to the layers and materials given, and it provided thicknesses, conductivity, emissivity, U-Value and R-value. This progress has prepared all models to be ready for simulation and evaluation with respect to each concern and criteria that will be mentioned in chapter 5 much more in depth and demonstration.

CHAPTER 5

SIMULATION RESULTS AND DISCUSSIONS

5.1 Introduction

In this stage, models are created according to a scenario, and the setup for the different profiles is done, this chapter will discuss each stage and analyze outcomes, then a highlight will focus on the concerns about the combination between a good lighting and reduced electrical values for a healthy classroom. Findings obtained in simulations will be used to investigate through tables and charts. The best classroom setting will be considered the recommended benchmark as the best performance. Simulation will commence by analyzing basic cases of the 3 classrooms where the first phase will evaluate classes without dimmers, and then the second phase will assess classrooms with sensors and dimming profile.

5.2 First phase (classrooms without dimmers)

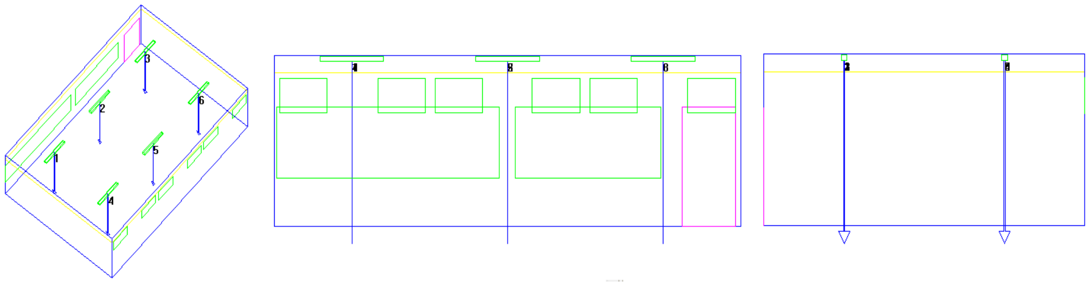


Figure (5.1) Isometric, left and front sides for a generic classroom shows artificial lights distribution (IES)

To begin with results and comparisons discussion, first stage will primarily evaluate the base case of the three classrooms of schools and assess their values in the main 4 orientations in the current status with the 6 tube lights as shown in figure (5.1). All models without dimmers have shown the same behavior in terms of lights electricity performance in KW in the peak day of Sunday January 11th as shown in figure (5.2), and this result was the same in the 12 models that don’t have sensor. Electricity runs from zero at 5:30 to reach its maximum at 06:00 and works consistently to 14:30 until students dismiss. Then, lighting electricity and AC will switch off by 15:30 to go back to zero, and the next day will be the same repeat.

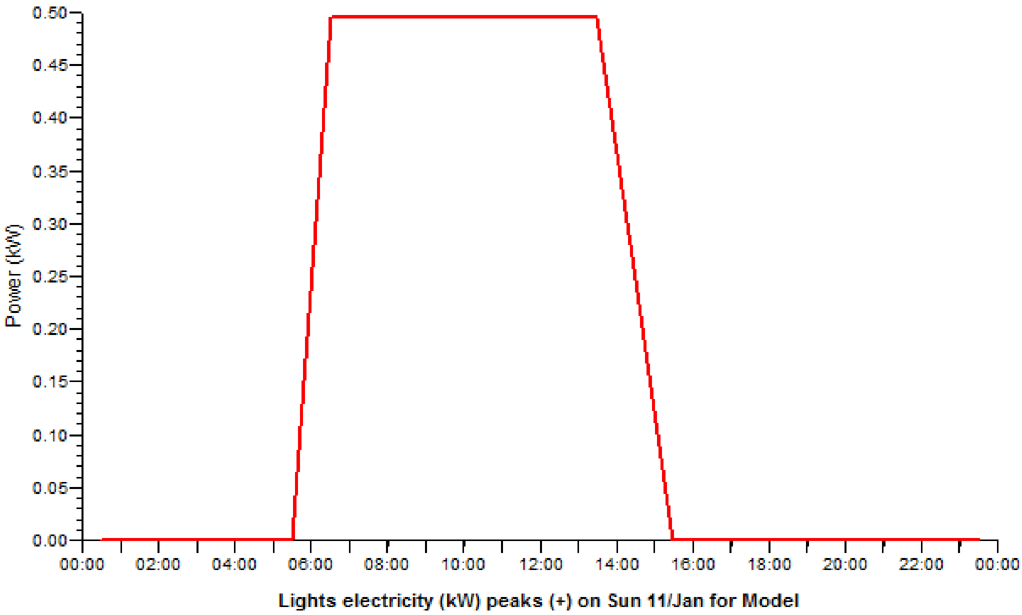


Figure (5.2) lights electricity peak day outcome for all models (IES)

Table (5.1) displays room cooling plant sensible load results where the 12 models were simulated to assess their consumption. At classrooms, summed total loads indicates that 596 West records the lowest annual cooling load of 26.5% lower than the highest value gained from KAT East configuration.

Table (5.1) Room cooling plant sensible load - table for all classrooms base case (IES)

Date	KAT West	KAT South	KAT North	kat-East	596 West	596 South	596 North	596 East	586 West	586 South	586 North	586 East
Jan 01-31	0.0042	0.0124	0.0144	0.0044	0.0057	0.0063	0.0037	0.0355	0.0023	0.0025	0.0014	0.0128
Feb 01-28	0.0556	0.072	0.0779	0.0571	0.0434	0.0653	0.0456	0.1152	0.0257	0.0361	0.0275	0.0652
Mar 01-31	0.2688	0.2409	0.2449	0.2726	0.1862	0.2454	0.2186	0.2331	0.1778	0.2233	0.2048	0.2116
Apr 01-30	0.523	0.4551	0.4564	0.525	0.3661	0.4439	0.4165	0.3772	0.3949	0.4663	0.4432	0.4056
May 01-31	1.0804	0.9521	0.9521	1.0846	0.7643	0.8925	0.8548	0.7647	0.8603	0.9787	0.9484	0.8604
Jun 01-30	1.0222	0.9226	0.922	1.0263	0.7414	0.8393	0.809	0.7369	0.8431	0.9332	0.9095	0.8381
Jul 01-31	0	0	0	0	0	0	0	0	0	0	0	0
Aug 01-31	0.0775	0.0719	0.072	0.0776	0.0566	0.0631	0.0611	0.058	0.0649	0.0708	0.0691	0.0662
Sep 01-30	1.1925	1.1312	1.1355	1.1959	0.8913	0.9801	0.9488	0.9342	1.0112	1.0922	1.0662	1.0494
Oct 01-31	0.8291	0.829	0.8369	0.8335	0.638	0.6912	0.6624	0.7255	0.7029	0.7507	0.7262	0.7768
Nov 01-30	0.4802	0.5324	0.5447	0.484	0.3898	0.4198	0.3865	0.5272	0.3938	0.4212	0.3918	0.5068
Dec 01-31	0.0104	0.0284	0.0324	0.0103	0.0132	0.0105	0.0107	0.0626	0.0071	0.007	0.0066	0.0288
Summed total	5.5439	5.2479	5.2892	5.5713	4.096	4.6574	4.4177	4.57	4.484	4.9819	4.7948	4.8217

In this case, there is no sensor and classrooms with the same volume will have the same lighting annual electricity consumption, and it is clear in Table (5.2) that the values of lights electricity –which are equal to the total lights energy values- have consumed in both models of 586 and 596 load of 0.7314 MWh, while KAT rooms consumed 0.835 MWh. These values will be compared afterward with the dimming case to observe the possible saving amounts that can be harvested when using sensors in classrooms.

Table (5.2) Lights electricity - table for all classrooms base case (IES)

Date	KAT West	KAT South	KAT North	kat-East	596 West	596 South	596 North	596 East	586 West	586 South	586 North	586 East
Jan 01-31	0.0624	0.0624	0.0624	0.0624	0.0546	0.0546	0.0546	0.0546	0.0546	0.0546	0.0546	0.0546
Feb 01-28	0.0912	0.0912	0.0912	0.0912	0.0799	0.0799	0.0799	0.0799	0.0799	0.0799	0.0799	0.0799
Mar 01-31	0.096	0.096	0.096	0.096	0.0841	0.0841	0.0841	0.0841	0.0841	0.0841	0.0841	0.0841
Apr 01-30	0.0672	0.0672	0.0672	0.0672	0.0588	0.0588	0.0588	0.0588	0.0588	0.0588	0.0588	0.0588
May 01-31	0.096	0.096	0.096	0.096	0.0841	0.0841	0.0841	0.0841	0.0841	0.0841	0.0841	0.0841
Jun 01-30	0.0768	0.0768	0.0768	0.0768	0.0673	0.0673	0.0673	0.0673	0.0673	0.0673	0.0673	0.0673
Jul 01-31	0	0	0	0	0	0	0	0	0	0	0	0
Aug 01-31	0.0048	0.0048	0.0048	0.0048	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
Sep 01-30	0.0912	0.0912	0.0912	0.0912	0.0799	0.0799	0.0799	0.0799	0.0799	0.0799	0.0799	0.0799
Oct 01-31	0.0912	0.0912	0.0912	0.0912	0.0799	0.0799	0.0799	0.0799	0.0799	0.0799	0.0799	0.0799
Nov 01-30	0.1056	0.1056	0.1056	0.1056	0.0925	0.0925	0.0925	0.0925	0.0925	0.0925	0.0925	0.0925
Dec 01-31	0.0528	0.0528	0.0528	0.0528	0.0462	0.0462	0.0462	0.0462	0.0462	0.0462	0.0462	0.0462
Summed total	0.835	0.835	0.835	0.835	0.7314	0.7314	0.7314	0.7314	0.7314	0.7314	0.7314	0.7314

In Table (5.3), values consumed in the total electricity have fallen in the range between 2.944- 3.8 MWh. The least consumption was in the model 596 West while the highest value was in the KAT West. Bearing in mind that the lights run continuously as per the scheduled daily profile along the school time is done, and then it’s switched of manually until the next day.

Table (5.3) Total electricity - table for all classrooms base case (IES)

Date	KAT West	KAT South	KAT North	kat-East	596 West	596 South	596 North	596 East	586 West	586 South	586 North	586 East
Jan 01-31	0.0717	0.0753	0.0762	0.0718	0.0635	0.0639	0.0626	0.078	0.0624	0.0627	0.0621	0.067
Feb 01-28	0.1281	0.1362	0.1391	0.1288	0.1095	0.1204	0.1106	0.1453	0.1009	0.106	0.1018	0.1204
Mar 01-31	0.2434	0.2295	0.2315	0.2453	0.1886	0.2181	0.2047	0.212	0.1845	0.2072	0.198	0.2014
Apr 01-30	0.3375	0.3035	0.3042	0.3385	0.2495	0.2884	0.2747	0.2551	0.264	0.2997	0.2881	0.2693
May 01-31	0.6537	0.5895	0.5896	0.6558	0.4812	0.5453	0.5265	0.4814	0.5295	0.5887	0.5735	0.5295
Jun 01-30	0.616	0.5662	0.5659	0.618	0.4618	0.5108	0.4957	0.4596	0.5132	0.5583	0.5464	0.5107
Jul 01-31	0	0	0	0	0	0	0	0	0	0	0	0
Aug 01-31	0.0464	0.0436	0.0437	0.0465	0.0349	0.0381	0.0371	0.0356	0.0391	0.0421	0.0412	0.0398
Sep 01-30	0.7416	0.711	0.7132	0.7433	0.5712	0.6156	0.5999	0.5926	0.6325	0.673	0.66	0.6516
Oct 01-31	0.5346	0.5346	0.5385	0.5368	0.4235	0.4501	0.4357	0.4672	0.4564	0.4804	0.4681	0.4934
Nov 01-30	0.3636	0.3897	0.3958	0.3655	0.3028	0.3178	0.3012	0.3715	0.305	0.3187	0.304	0.3615
Dec 01-31	0.0632	0.0722	0.0742	0.0631	0.0574	0.056	0.0561	0.0821	0.0543	0.0543	0.0541	0.0652
Summed total	3.7998	3.6513	3.6719	3.8135	2.9439	3.2247	3.1047	3.1804	3.1419	3.391	3.2974	3.3098

The impact of solar intensity on each model and direction are different, and obtained light levels are sensitive to the room envelope. Results acquired in Table (5.4) point out that the least solar gain was in 596 west – which has a double glazing - was 3.6208 MWh, and that is less than the highest by 46.4% which belongs to 586 north that gets a strong solar exposure from the glazing in the afternoon period. These values will be considered in the next stage of sustainable design decisions after analyzing the current status of the basic cases.

Table (5.4) Solar gain - table for all classrooms base case (IES)

Date	596 West	596 South	596 North	596 East	586 West	586 South	586 North	586 East
Jan 01-31	0.3533	0.3665	0.3844	0.6747	0.4081	0.4166	0.4359	0.7465
Feb 01-28	0.3249	0.4357	0.4495	0.5995	0.3785	0.4914	0.5066	0.6734
Mar 01-31	0.3175	0.5003	0.5142	0.4525	0.3695	0.5658	0.5806	0.5225
Apr 01-30	0.2763	0.5381	0.537	0.3217	0.3201	0.6073	0.6046	0.3776
May 01-31	0.26	0.5963	0.6087	0.2584	0.3	0.674	0.6868	0.2987
Jun 01-30	0.2624	0.5738	0.5816	0.2432	0.3041	0.6489	0.6584	0.2795
Jul 01-31	0.2764	0.5675	0.5746	0.2673	0.318	0.6419	0.6494	0.3065
Aug 01-31	0.2537	0.5581	0.5677	0.2811	0.2943	0.6318	0.6408	0.3309
Sep 01-30	0.2721	0.5072	0.5181	0.3923	0.3205	0.5734	0.5854	0.4617
Oct 01-31	0.3336	0.4739	0.4802	0.5924	0.3903	0.5362	0.5436	0.6719
Nov 01-30	0.342	0.3996	0.3989	0.6589	0.3964	0.4545	0.453	0.7319
Dec 01-31	0.3486	0.3527	0.3627	0.6713	0.4021	0.4019	0.4111	0.7408
Summed total	3.6208	5.8698	5.9775	5.4134	4.2019	6.6436	6.7561	6.1418

5.3 Second phase (classrooms with dimmers)

This stage was prepared after creating the basic classrooms current status. In this section, the previous 12 classrooms are fitted with dimming profile to activate the sensors by using RadianceIES from the IES software. These 2 sensors were located on a height of 0.75m from the workplane looking upwards and they were added in the middle of the classroom. Figure (5.3) illustrates arrangement of the 6 artificial lights which are positioned on a grid of 2 by 3 as shown in the left plan drawing with respect to classrooms proportion. The aim of having 2 sensors is to place one in the deep area and another one close to the window side, so whenever there is no sufficient lighting from one of either locations, artificial lights will turn on or they will maintain off; and that will assist in reducing electrical consumptions.

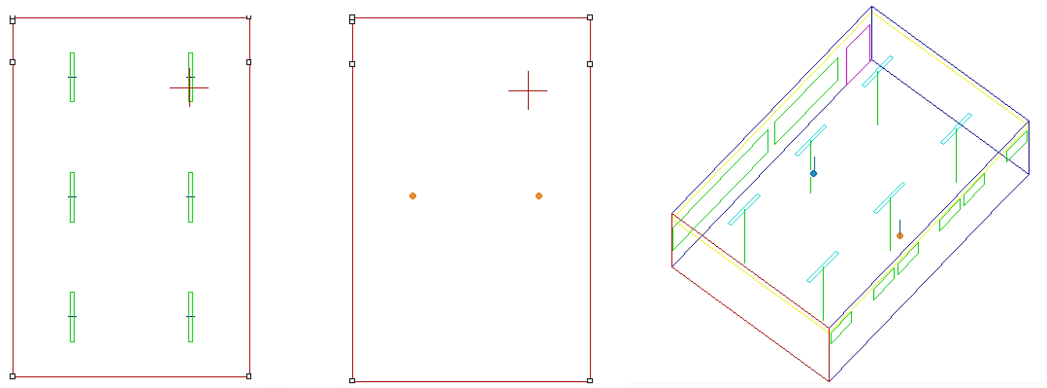


Figure (5.3) Drawings for the 2 sensor added on 0.75m height in all classrooms (IES)

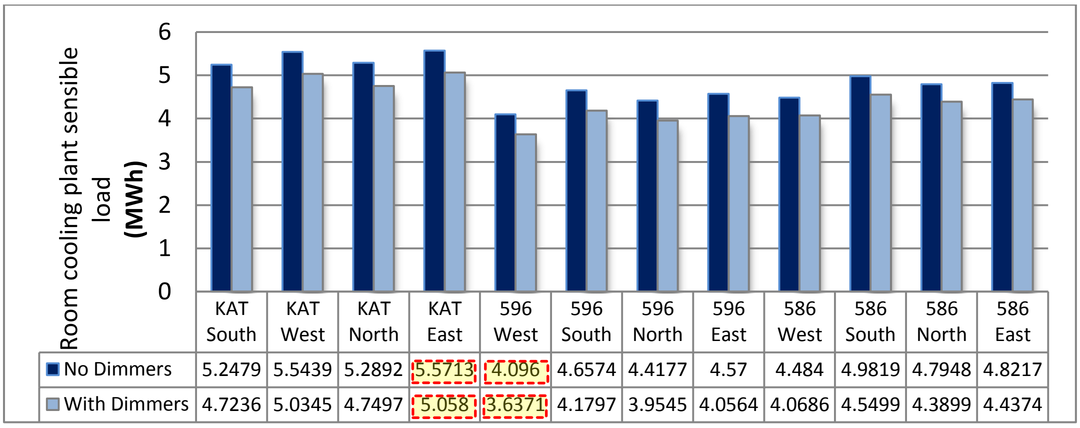
After adding sensors to the lighting system in the classrooms, there was a reduction in room cooling plant sensible load. The amount of loads reduced varies from 3.46-9.20 % from the lowest to highest values of all cases results as listed in Table (5.5). In the basic case before dimmers, 596 west was the lowest result as .096 MWh, similarly after lighting dimmers it recorded the 1st and best in saving amounts where consumption achieved 3.6371 MWh.

Table (5.5) Room cooling plant sensible load - table for all classrooms with dimmers (IES)

Date	KAT west Dimming	KAT South Dimming	KAT North Dimming	KAT East Dimming	596 west Dimming	596 south Dimming	596 north Dimming	596 east Dimming	586 west Dimming	586 south Dimming	586 North Dimming	586 East Dimming
Jan 01-31	0.0008	0.0045	0.0052	0.0009	0.0015	0.0018	0.0006	0.0193	0.0002	0.0001	0	0.0054
Feb 01-28	0.0265	0.0377	0.0411	0.0264	0.0184	0.0301	0.0196	0.0727	0.0111	0.0167	0.013	0.0379
Mar 01-31	0.2122	0.19	0.1912	0.215	0.1409	0.1899	0.1672	0.1803	0.1422	0.1774	0.1661	0.1747
Apr 01-30	0.4717	0.4055	0.4038	0.4733	0.3192	0.3968	0.3695	0.3301	0.3501	0.4211	0.4006	0.3758
May 01-31	1.0055	0.8785	0.877	1.0095	0.6965	0.8247	0.7869	0.6967	0.7954	0.9138	0.8859	0.8162
Jun 01-30	0.9628	0.8641	0.8624	0.9666	0.6869	0.7847	0.7545	0.6824	0.7908	0.8809	0.861	0.8009
Jul 01-31	0	0	0	0	0	0	0	0	0	0	0	0
Aug 01-31	0.0738	0.0682	0.0684	0.0739	0.0533	0.0598	0.0578	0.0547	0.0618	0.0676	0.066	0.0639
Sep 01-30	1.1199	1.0588	1.0628	1.1234	0.8265	0.9152	0.884	0.8694	0.9491	1.03	1.0051	0.9941
Oct 01-31	0.7572	0.7567	0.7644	0.7614	0.5736	0.6265	0.5979	0.661	0.6411	0.6887	0.6655	0.7171
Nov 01-30	0.3981	0.4486	0.4604	0.4017	0.3148	0.3447	0.3114	0.452	0.3223	0.3494	0.3229	0.4379
Dec 01-31	0.0059	0.0111	0.0129	0.0059	0.0055	0.0054	0.005	0.0377	0.0042	0.0041	0.0037	0.0136
Sum med total	5.0345	4.7236	4.7497	5.058	**3.6371**	4.1797	3.9545	4.0564	4.0686	4.5499	4.3899	4.4374

5.4 Comparison between first and second phase models

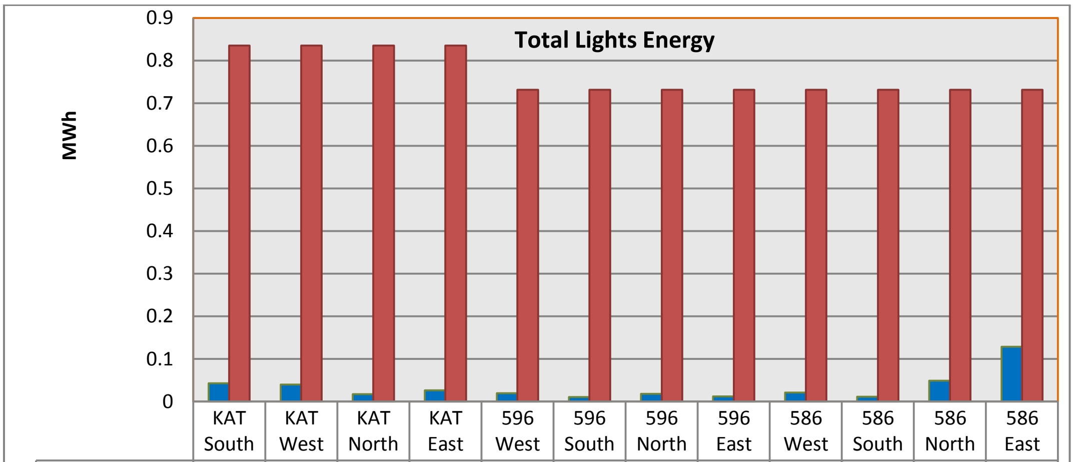
In this part of analysis, the two modeling phases will be combined in tables and figures to compare them before and after lighting dimming profiles. In figure (5.4), room cooling plant sensible load shows that there is a general reduction in all models after adding the sensors which is around 11% if compared with the base cases without dimmers. Out of the 24 models, the 596 West produced the minimum amount of cooling loads as 3.6371 MWh.



	KAT South	KAT West	KAT North	KAT East	596 West	596 South	596 North	596 East	586 West	586 South	586 North	586 East
No Dimmers	5.2479	5.5439	5.2892	5.5713	4.096	4.6574	4.4177	4.57	4.484	4.9819	4.7948	4.8217
With Dimmers	4.7236	5.0345	4.7497	5.058	3.6371	4.1797	3.9545	4.0564	4.0686	4.5499	4.3899	4.4374

Figure (5.4) Room cooling plant sensible load - with and without dimmers (IES)

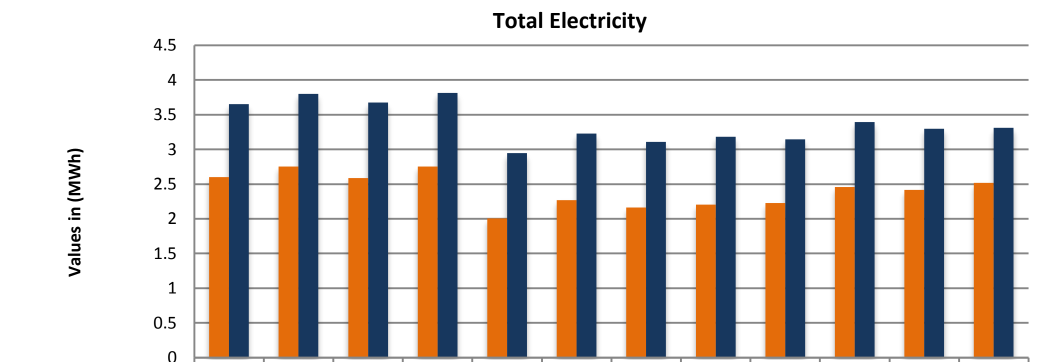
Figure (5.5) shows the amounts of total lights energy which is another primary concern in addition to the cooling sensible loads. It showed the 24 classrooms where “without dimmers” is shown in red and “with dimmers” in blue color, and apparently all scenarios without dimmer consumed the most when compared to the dimmers models. The least value obtained with dimmers was 596 south 0.0109 MWh, then 586 south 0.0113 MWh. It’s important to highlight that 596 west indicated the 6th rank –but with a small margin- in saving a total of 0.0199 MWh out of the 24 models.



	KAT South	KAT West	KAT North	KAT East	596 West	596 South	596 North	596 East	586 West	586 South	586 North	586 East
With Dimmers	0.0434	0.0404	0.0174	0.0267	0.0199	0.0109	0.0182	0.012	0.0214	0.0113	0.0491	0.1288
No Dimmer	0.835	0.835	0.835	0.835	0.7314	0.7314	0.7314	0.7314	0.7314	0.7314	0.7314	0.7314

Figure (5.5) Total lights energy - with and without dimmers (IES)

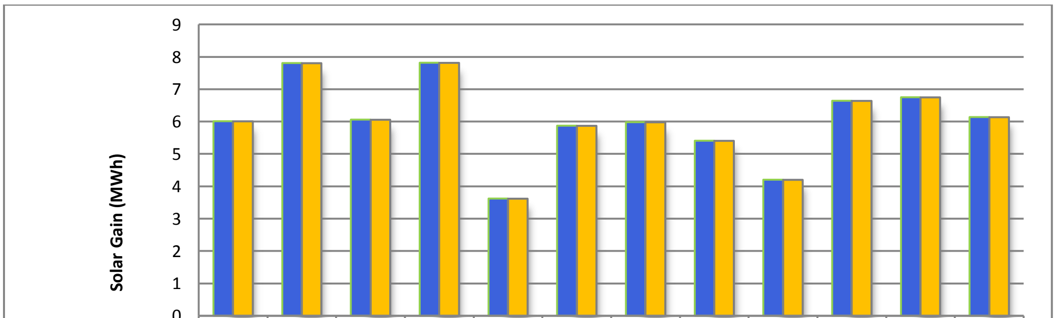
Effect of the dimmer profile reduced all classrooms results. In figure (5.6) 596 west recorded the least classroom with dimmer and sensor which reached 2.0037 MWh, and that means that the classroom daylighting was efficient in many days of the year, but lights were running with the standard profile, so it consumed a lot of unrequired electrical energy for lights. It’s reasonable to find good reduction in the records of classrooms after adding the new dimming profile; due to the glazing which allows good amount of daylighting in the space, yet subtracts the need of artificial lights and reduce cooling levels consequently.



	KAT South	KAT West	KAT North	KAT East	596 West	596 South	596 North	596 East	586 West	586 South	586 North	586 East
With Dimmers	2.5981	2.7514	2.5853	2.7496	2.0037	2.2663	2.1609	2.2046	2.2251	2.456	2.4135	2.5156
No Dimmer	3.6513	3.7998	3.6719	3.8135	2.9439	3.2247	3.1047	3.1804	3.1419	3.391	3.2974	3.3098

Figure (5.6) Total electricity with and without dimmers (IES)

Information provided in figure (5.7) display equal values for the 12 classrooms of the first and second phase –with and without dimmers- and that occurred because it studied the solar gain values which is related to the amount of solar radiation that is absorbed on the room surface and it will be the same amount of incident solar radiation for each case independently. Eastern, northern and southern scenarios have the maximum exposure among the school model, while the western models of 586 and 596 have the least solar gain values. All models’ scenarios had an output which was influenced by the solar gain; however the 596 west gained a significant amount of 3.6208 MWh where its parameters were positively helpful to reduce solar radiation which heat up the internal room.



	KAT South	KAT West	KAT North	KAT East	596 West	596 South	596 North	596 East	586 West	586 South	586 North	586 East
No Dimmers	6.0156	7.8076	6.06	7.817	3.6208	5.8698	5.9775	5.4134	4.2019	6.6436	6.7561	6.1418
With Dimmers	6.0156	7.8076	6.06	7.817	3.6208	5.8698	5.9775	5.4134	4.2019	6.6436	6.7561	6.1418

Figure (5.7) Solar gain values with and without dimmers (IES)

With respect to results obtained and shown in all above figures, classrooms with the dimmers have repeatedly achieved the best saving values and electrical lighting reduction along the annual testing period. For that, it’s essential in this stage to break down these models; to classify the minimum achieved values and compare them to decide which one of these scenarios can be selected as the best base case. As a result it will be the new bench mark for the new scenarios which aims to introduce solutions for better lighting uniformity at classroom within a sustainable environment.

5.4.1 Comparing 24 models outcomes

The presence of solar radiation at classrooms has an effect on the internal space and it will provide heat and light simultaneously. In room cooling plant, 596 west with dimmers gained the lowest load. Concerning the total lights energy results, 596 south with dimmers obtained the least value. The minimum total electricity was recorded in 596 west model after adding dimmers which is among the total of 24 models. 596 west was also the classroom which gained the least solar radiation as assessed and discussed before.

With reference to the Table (5.6), the 12 classrooms fitted with dimmers have been assorted and analyzed on the table –because all rooms without dimmers presented much higher values- and that will identify the best classroom which has the most economic energy performance and the least electrical consumption among the others, and in the next phase, this classroom will present the new base case that will be used in the next stage of simulations and comparisons; to define the ways to reduce energy and maintain the classroom in a healthy and ecological atmosphere.

Table (5.6) Variables comparison between classrooms with dimmers

1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Room cooling plant sensible load											
596 West	596 North	596 East	586 West	596 South	586 North	586 East	586 South	KAT South	KAT North	KAT West	KAT East
3.6371	3.9545	4.0564	4.0686	4.1797	4.3899	4.4374	4.5499	4.7236	4.7497	5.0345	5.058
Total lights energy											
596 South	586 South	596 East	KAT North	596 North	596 West	586 West	KAT East	KAT West	KAT South	586 North	586 East
0.0109	0.0113	0.012	0.0174	0.0182	0.0199	0.0214	0.0267	0.0404	0.0434	0.0491	0.1288
Total electricity											
596 West	596 East	596 North	586 West	596 South	586 North	586 South	586 East	KAT North	KAT South	KAT East	KAT West
2.0037	2.2046	2.1609	2.2251	2.2663	2.4135	2.456	2.5156	2.5853	2.5981	2.7496	2.7514
Solar Gain											
596 West	586 West	596 East	596 South	596 North	KAT South	KAT North	586 East	586 South	586 North	KAT West	KAT East
3.6208	4.2019	5.4134	5.8698	5.9775	6.0156	6.06	6.1418	6.6436	6.7561	7.8076	7.817

* All models in the table above are with dimmers

* All variables shown above were the summed totals in (MWh)

596 west classroom ranked the first in room cooling plant sensible load, total lights energy, total electricity and solar gain. On the other hand, 596 south was the first in total lights energy then it got 4th in cooling loads and solar gains and the 5th in total electricity. Bearing in mind that the main concerns in this research is to investigate sufficiency of daylighting level at the classroom with the least cooling and electricity loads. Consequently, all results above recommended 596 west with dimmers as the best choice for the new base case. According to this assumption, the 596 west with dimmers it will be considered the new base case with the new parameters and criteria which will evaluate energy assessment values and daylighting distribution and uniformity at the classroom, and it will be identified as 596WD in the research.

5.4.2 596WD lighting analysis

To understand more the impact of the building envelope design on daylighting performance, a calculation was conducted for the 596WD to measure its lighting capabilities. By the aid of available modules in VE, a lighting design was performed to analyze the classroom according to the fitted existing lights, show lighting schemes and simulations using FlucsPro, LightPro and RadianceIES. The following calculations will demonstrate the results of the best scenario among the others in term of lighting internally according to the calculation data mentioned in Table (5.7) that showed the referred data while simulating the room.

Table (5.7) Summery calculation for 596WD on the working planes and flooring (IES)

Calculation Data	
Location	Dubai Intl Airport, United Arab Emirates (25.25 N, 304.67 W)
Calculated	01 Jun 2016 at 9:23
Sky Model	CIE Clear Sky at 21 Mar 12:00
Working plane height	0.750m
Grid Size	0.500m
Illuminance Threshold (%)	1.000
Light Penetration	No light penetration through internal windows

Design calculations for 596WD show that the number of artificial parallel lights is 2x3 in a total of 6 tub lights. The power in watts reached 276, while illuminance was 111 lux. The room achieved 16.75 but gained glare. This assumption is due to the high illumination value which was design to be 500 lux. Regarding the Daylighting Factor (DF), Inan (2013) and Abdelatia, Marenne and Semidor (2010) mentioned that 2% of DF should be available in the classroom as a minimum level. Inan (2013) added that 5% or more will not require any electric light and 269 lux is the minimum required level, while Lim et al. (2012) stated that 6% and above will produce glare in the space and create some thermal problems. As an overview for the working planes and flooring results where the total area is 37.4 m2, the quantity of (DF) as listed in Table (5.8) reached a minimum of 2.6% and a maximum of 12.3%, while the daylighting illuminance minimum was 224.5 lux and maximum 1085 lux and the average illumination is 513 lux which is close to the sufficient level of 500 lux, and the sum of artificial usage is zero. The software listed some recommendations for the room like increasing the total glazing amounts and considering their shape and size; to have better daylighting results with the least glare levels.

Table (5.8) Summery calculation for 596WD on the working planes and flooring (IES)

Surface	Quantity	Values			Uniformity (Min./Ave.)	Diversity (Min./Max.)
		Min.	Ave.	Max.		
Working plane 1 Reflectance=0% Transmittance=100% Grid size=0.50 m Area=37.440m² Margin=0.50 m	Artificial illuminance	0.00 lux	0.00 lux	0.00 lux	0.00	0.00
	Daylight factor	2.6 %	5.8 %	12.3 %	0.44	0.21
	Daylight illuminance	224.54 lux	512.89 lux	1085.07 lux	0.44	0.21
	Sky view	1.00	1.00	1.00	1.00	1.00
	Total illuminance	224.54 lux	512.89 lux	1085.07 lux	0.44	0.21

Daylight level reached 1050 lux in March 21st at 12:00 as shown in figure (5.8). This level was measured for the combined case, but as illustrated before that artificial light didn't work; because the natural light was sufficient to cover all areas of the classroom. In figure (5.9) the lux level reached up to 475 as a maximum value near the window, and it decreased gradually with respect to the depth of the classroom until it reached 75 lux in the deep areas. It was clarified also in the perspective that 114 cd/m^2 was the maximum lighting obtained, and the average value was 80-100 cd/m^2 o the majority of the classroom space.

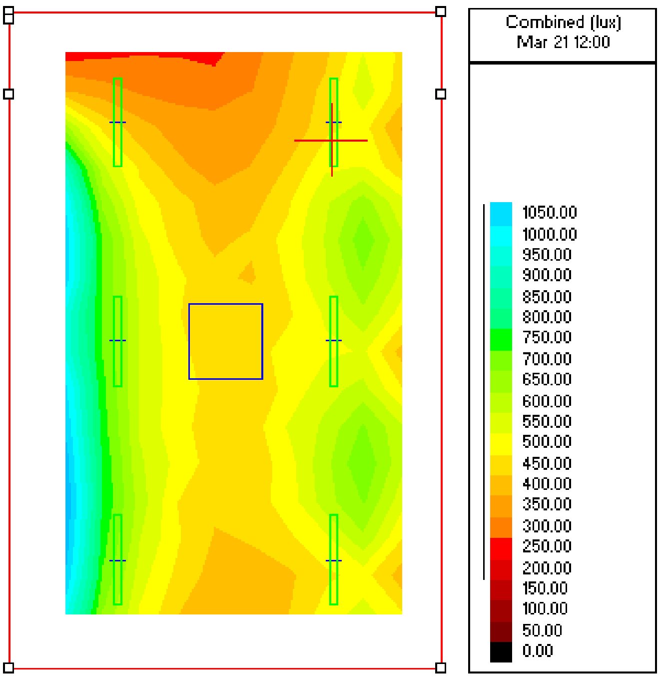


Figure (5.8) combined lux levels for 596WD in March 21 at 12:00

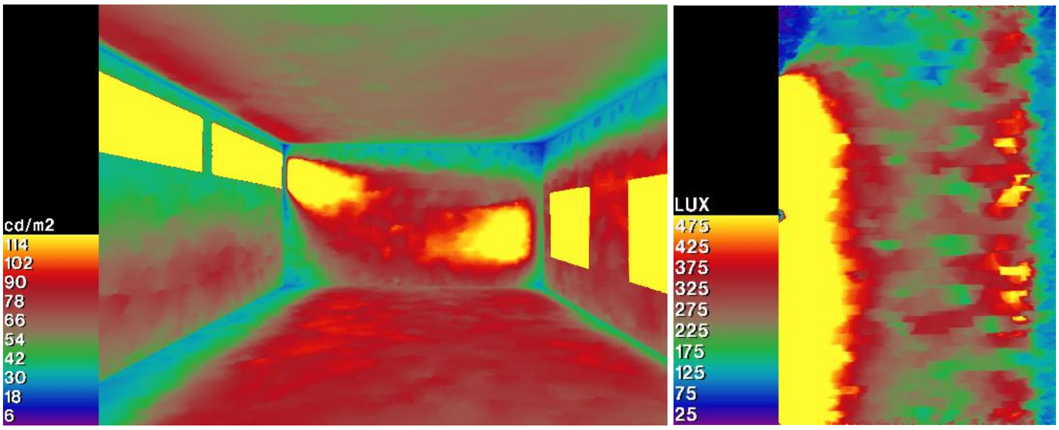


Figure (5.9) Contour plan and perspective for lux and cd/m^2 levels in 596WD

5.5 Structuring new scenarios with respect to 596WD

In this stage, 596WD classroom which is shown in figure (5.10) will have new enhancement configurations which take place in a new stage of modeling and simulation. That will base on new criteria which refer to the structure of room elements such as wall, window and roof. Generally speaking, there are important features which have the advantage to improve existing cases when studying the status of the model carefully and check the feasible options that can be done without raising expenses for the investor sake; if the offered solution and cost are reasonable and if the project has sustainable capacity and awareness.

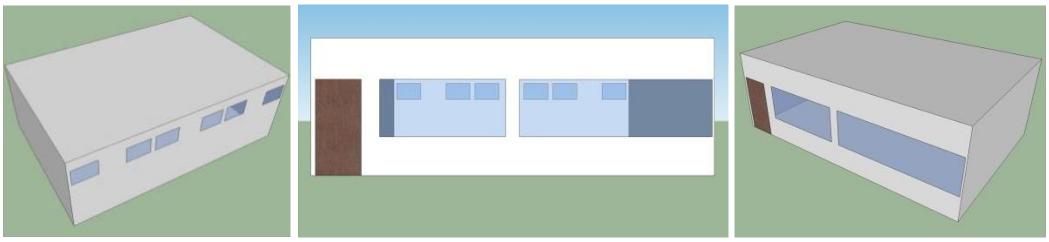


Figure (5.10) 596WD isometric as a new base case (Author)

Different Scenarios will be examined and presented in this section. Some of them will deal with the wall height to depth ratio (WHDR), window to wall ratio (WWR), window height to width ratio (WHWR), window position in the wall –like flush, middle or recessed inwards to the room- and others will concentrate on building construction materials which will be tested according to DM and Estidama regulations and U-Values. All of these options will have different attempts to evaluate the amounts of energy consumption and overall –sum of natural and artificial- lighting offered at classrooms. Figure (5.11) shows a prepared chart the structure which is based on main three pillars, starting with the wall aspect, then construction materials U-Values, and finally window aspect according to the chart which shows the grouping of each aspect, scenarios will be applied on the new base case –which is 596WD- and it will be modeled as per every sub-aspect's measurement to be ready for simulation and evaluation.

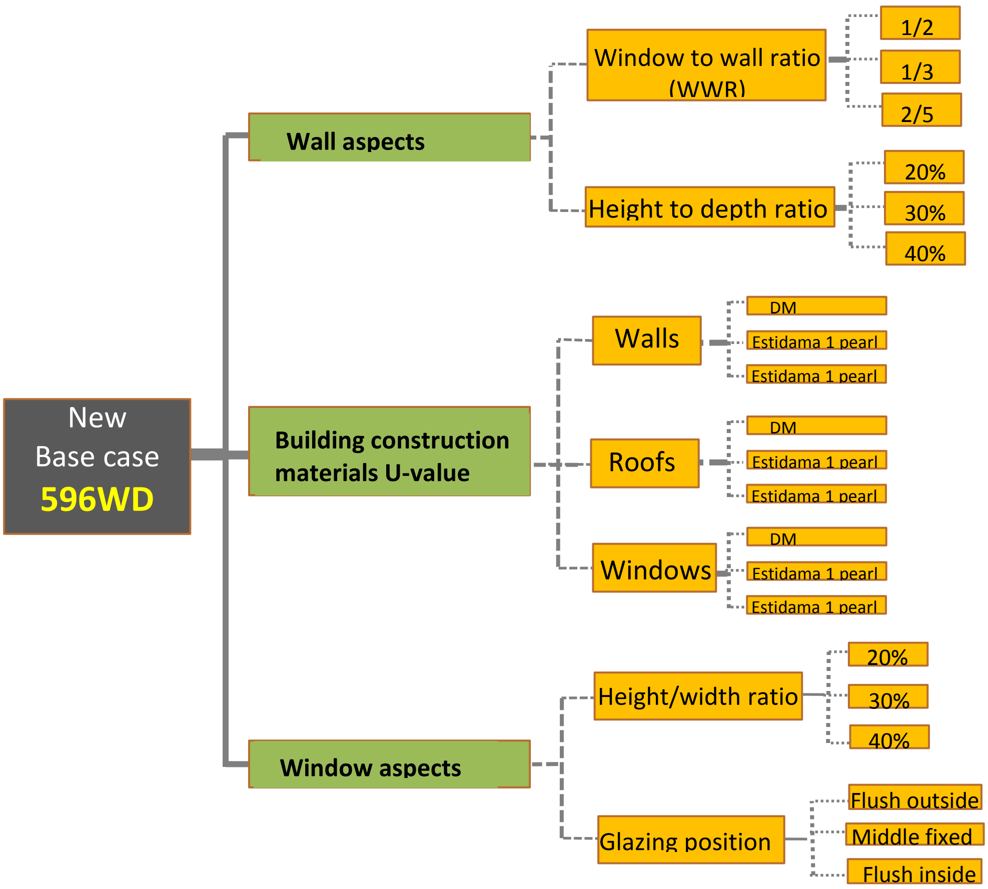


Figure (5.11) Parameters of analysis for the new base case (Author)

The selection of each aspect was decided with respect to the literature reviews and field experiments that have been discussed earlier in chapter 2 which were sharing similar sets of interest and the framework approach is constructive and beneficial for the author. Each of the main aspects in the figure will be explained afterward in further details with either isometric drawings or layer of materials; according to each aspect, and then it will be compared to each category to select the best result of each scenario.

5.5.1 Wall aspects

5.5.1.1 Height to depth ratio (WHDR)

Monitoring the depth of a classroom with respect to its height leads to a proper decision for the desired ratio in the space. As Al-Sallal (2010) clarified that designing with different depth values can be within a range of 4.6- 9.1m, and it should be managed respecting the fixed height of the classroom. So, an illuminance level of 300 lux can be achieved by a natural lighting. Al-Sallal (2010) added that if a 20% of glazing and WHDR of 1:2 in a room, the DF will reach 1.5- 2 as a good daylight value. By controlling this ratio –where depth aspect will change and height remains fixed- the experiment will show results; to explain more the impact of each scenario on energy consumption and daylighting amounts that can be achieved in the classroom by adjusting this aspect correctly.

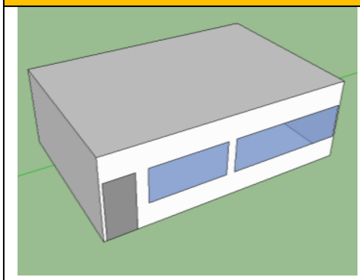
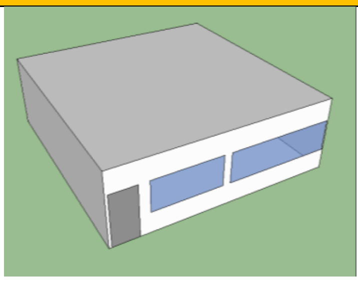
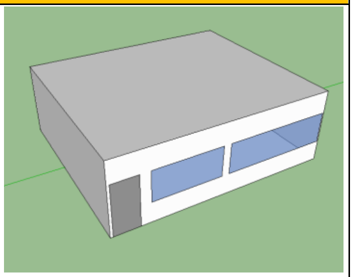
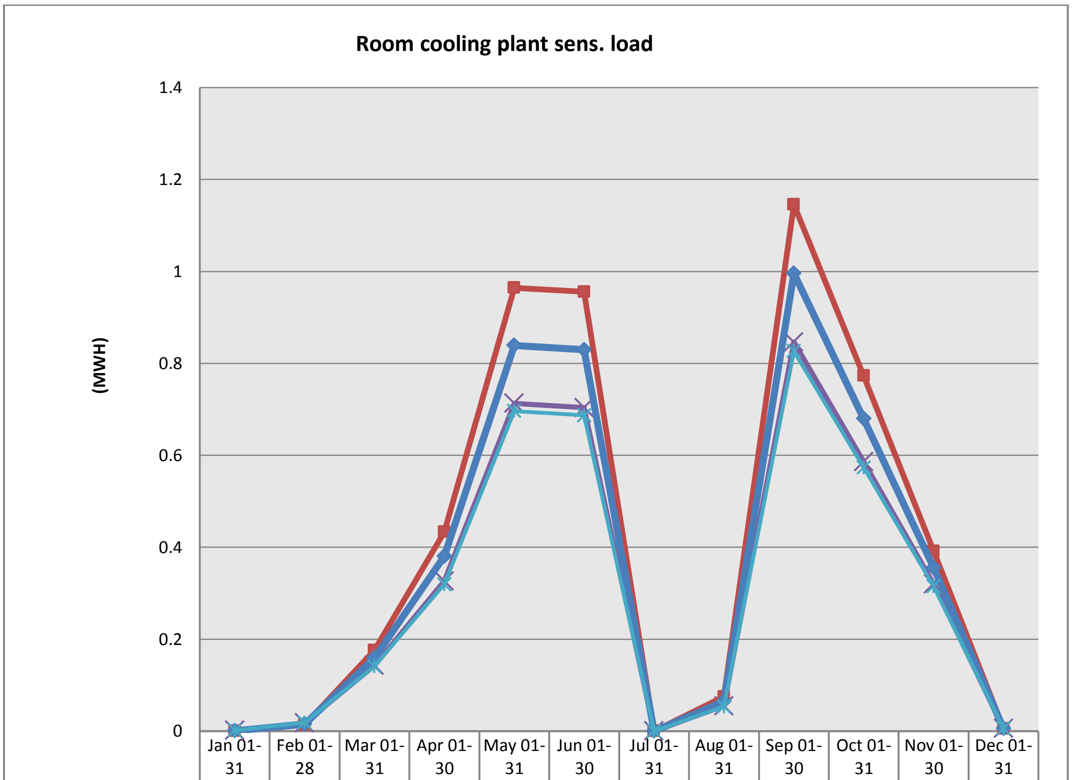
(1/2)	**(1/3)**	**(2/5)**
(6W x 3H) m	**(8.66W x 3H) m**	**(7.5W x 3H) m**
		

Figure (5.12) Height to depth ratio (WHDR) in 3 scenarios (Author)

In this aspect only, the volume of the classroom will be different in each of the assessed ratios which is concerned about the depth of the room with respect to its unchangeable height in the three ratios. For that, all results obtained from these rooms will be divided proportionally to match the base case volume as 153 cubic meters.

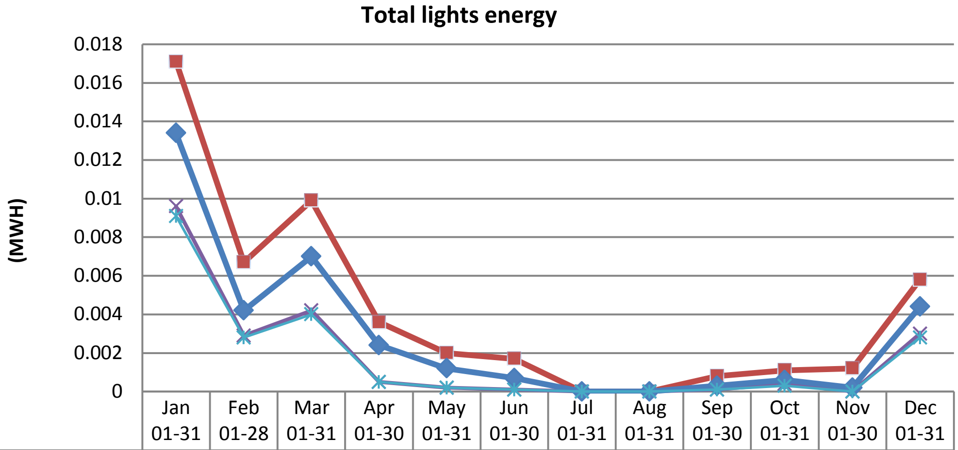
Room cooling plant in figure (5.13) indicates that (WHDR) results were obtained the least by the model 596WD. It achieved 3.637 MWh, while the ratio 1to2 obtained the second least value as 3.717 MWh.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
HtoD 1to2	0.0014	0.0179	0.1429	0.3262	0.7132	0.7037	0	0.0547	0.8465	0.5861	0.3196	0.0055
HtoD 1to3	0.0001	0.0137	0.1759	0.4333	0.9644	0.9559	0	0.075	1.1453	0.7731	0.3913	0.0054
HtoD 2to5	0.0006	0.0154	0.1592	0.3801	0.8391	0.8297	0	0.0649	0.9959	0.6796	0.3553	0.0055
596WD	0.0015	0.0184	0.1409	0.3192	0.6965	0.6869	0	0.0533	0.8265	0.5736	0.3148	0.0055

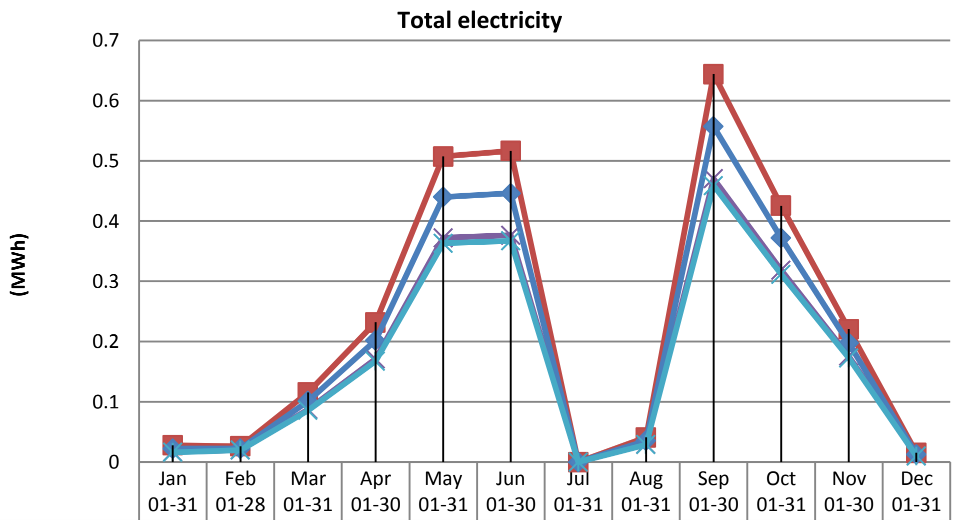
Figure (5.13) Room cooling plant sensible loads for WHDR scenarios

Total lights energy indicated in figure (5.14) the least value of 0.0199 MWh by 596WD and then 1 to 2 ratio which got 0.021 MWh. Similarly the results for total electricity shown below in figure (5.15) , The model 596WD was the first electricity reduction –which was 2.0037MWh- and the second was 1 to 2 ratio with 2.0508 MWh



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
HtoD 1to2	0.0096	0.0029	0.0042	0.0005	0.0002	0.0001	0	0	0.0001	0.0004	0	0.003
HtoD 1to3	0.0171	0.0067	0.0099	0.0036	0.002	0.0017	0	0	0.0008	0.0011	0.0012	0.0058
HtoD 2to5	0.0134	0.0042	0.007	0.0024	0.0012	0.0007	0	0	0.0003	0.0006	0.0002	0.0044
596WD	0.0091	0.0028	0.004	0.0005	0.0002	0.0001	0	0	0.0001	0.0003	0	0.0028

Figure (5.14) Total lights energy values for WHDR scenarios

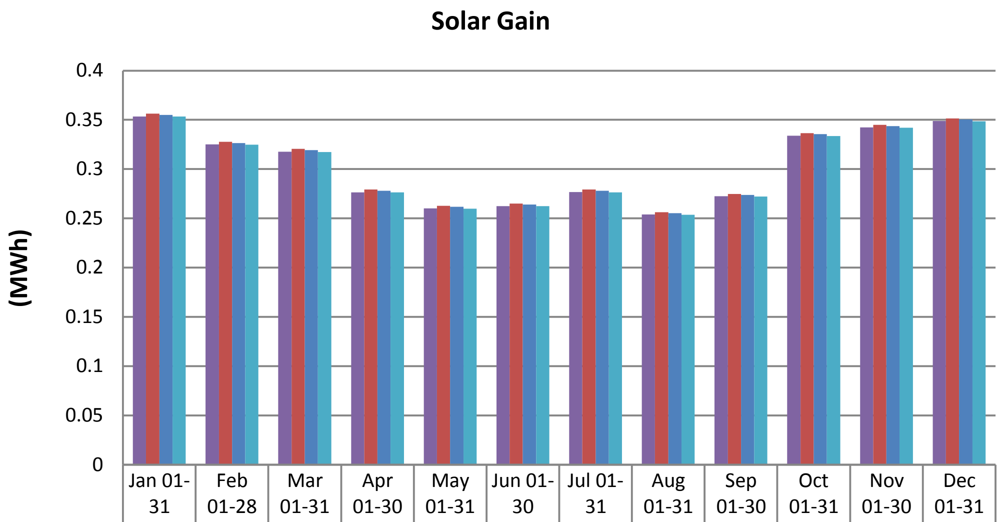


	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
HtoD 1to2	0.017	0.0202	0.0875	0.1715	0.3724	0.3766	0	0.0298	0.4706	0.3188	0.1758	0.0104
HtoD 1to3	0.028	0.0265	0.1157	0.2321	0.5075	0.5167	0	0.0412	0.6443	0.4259	0.2208	0.0155
HtoD 2to5	0.0225	0.0225	0.1014	0.2023	0.4402	0.4464	0	0.0355	0.5573	0.3722	0.1978	0.013
596WD	0.0163	0.0201	0.0859	0.1677	0.3634	0.3674	0	0.0291	0.4591	0.3117	0.1729	0.0101

Figure (5.15) Total electricity values for WHDR scenarios

Outcomes of the solar gain were not highly fluctuated, and the range was very narrow. As it shows in the values of figure (5.16) that 596WD and 1 to

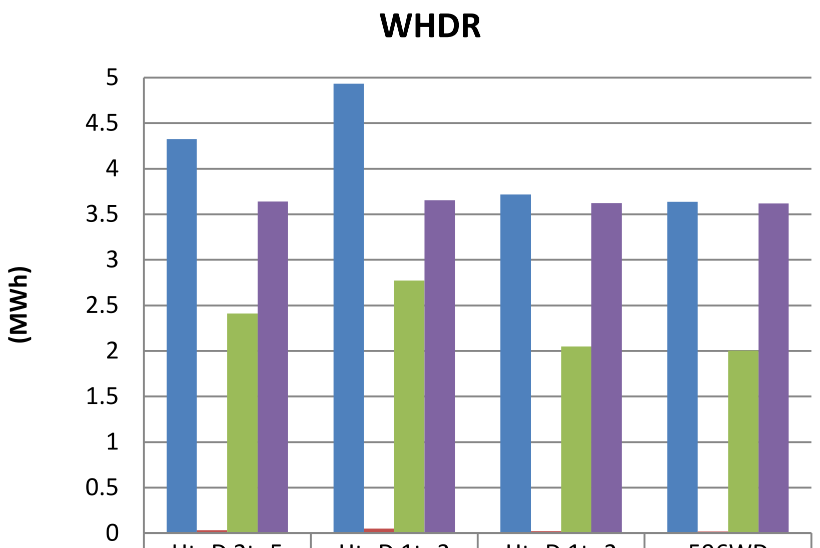
2 ratio got 3.6208 MWh and 3.6237 MWh respectively which are the least 2 values.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
HtoD 1to2	0.3535	0.3252	0.3178	0.2765	0.2602	0.2626	0.2767	0.2539	0.2724	0.3339	0.3422	0.3488
HtoD 1to3	0.3563	0.3277	0.3206	0.2792	0.2627	0.2651	0.2793	0.2564	0.2748	0.3366	0.3449	0.3516
HtoD 2to5	0.3551	0.3266	0.3194	0.2781	0.2617	0.2641	0.2782	0.2554	0.2738	0.3354	0.3438	0.3504
596WD	0.3533	0.3249	0.3175	0.2763	0.26	0.2624	0.2764	0.2537	0.2721	0.3336	0.342	0.3486

Figure (5.16) Solar gain values for WHDR scenarios

Simulation assessed for the height to depth ratio was run along the academic year. Results for the four models shown in figure (5.17) are briefed here to evaluate the best scenario among the others. WHDR in the model 596WD was the lowest in room cooling plant load as 3.6371MWh, and in total lights energy 596WD got the minimum as 0.0199 MWh, and it obtained in addition to this the total electricity which was 2.0037 MWh. Finally, solar gain was obtained the lowest in the model 596WD as 3.6208 MWh. For that, all variables selected to assess the models show that the 596WD is the best scenario in terms of height to depth ratio.



	HtoD 2to5	HtoD 1to3	HtoD 1to2	596WD
Room cooling plant sens. load	4.3254	4.9334	3.7177	3.6371
Total lights energy	0.0343	0.0499	0.021	0.0199
Total electricity	2.4112	2.7742	2.0508	2.0037
Solar gain	3.6419	3.6552	3.6237	3.6208

Figure (5.17) Total variables comparison between scenarios in WHDR

5.5.1.2 Window to wall ratio (WWR)

It's measured as the percentage of glazing –as a total fenestration- on the elevation versus the wall area which is not glazed. WWR is important to decide the amount of light and heat needed in the space. Teri (2010) mentioned in the section of openings that this ration can be calculated using the following formula:

$$\boxed{WWR = \frac{\text{Net glazing Area}}{\text{Gross exterior wall area}}}$$ (Teri 2010)

If the wall has low R-values WWR can reduce the incident heat in the room. Windows have a great impact on energy saving, and the excessive size of glazing in hot arid areas will raise cooling loads, especially when it's placed on the southern part of the building unless some shading devices are applied on façade, yet it's not considered as the best solution.

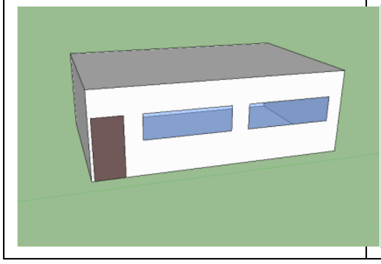
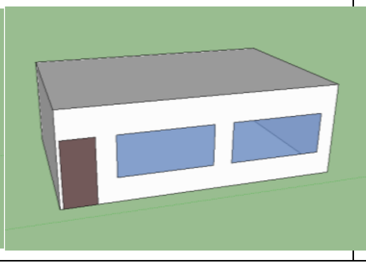
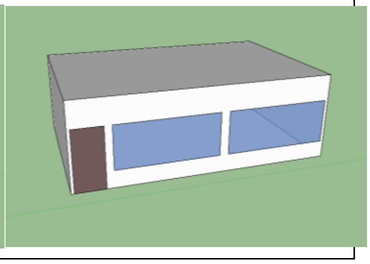
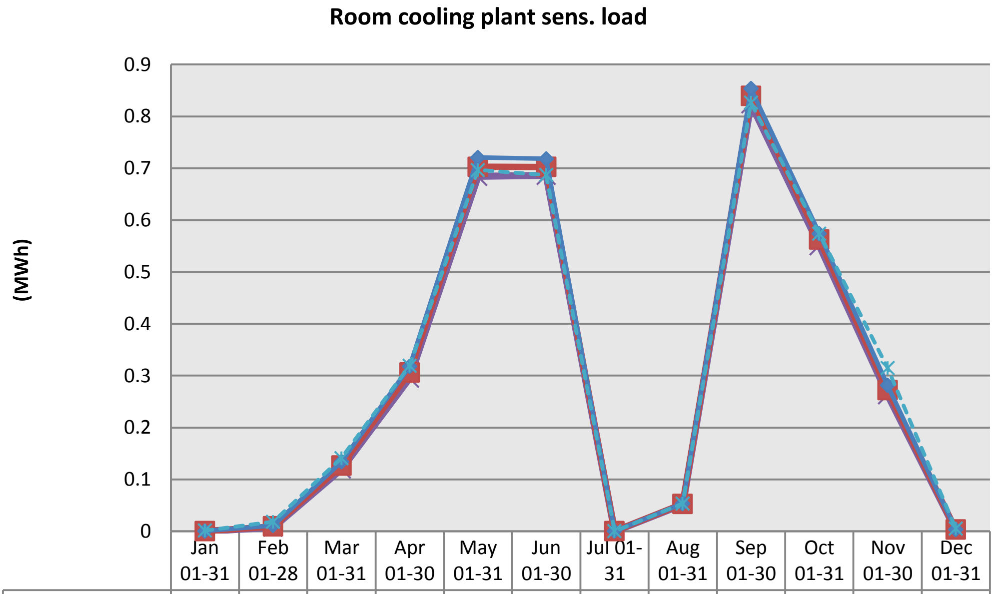
20%	30%	40%
(3.0 x 0.8m) per window	**(1.32 x 3.0m) per window**	**(3.52x 1.5m) per window**
		

Figure (5.18) WWR ratio in 3 scenarios (Author)

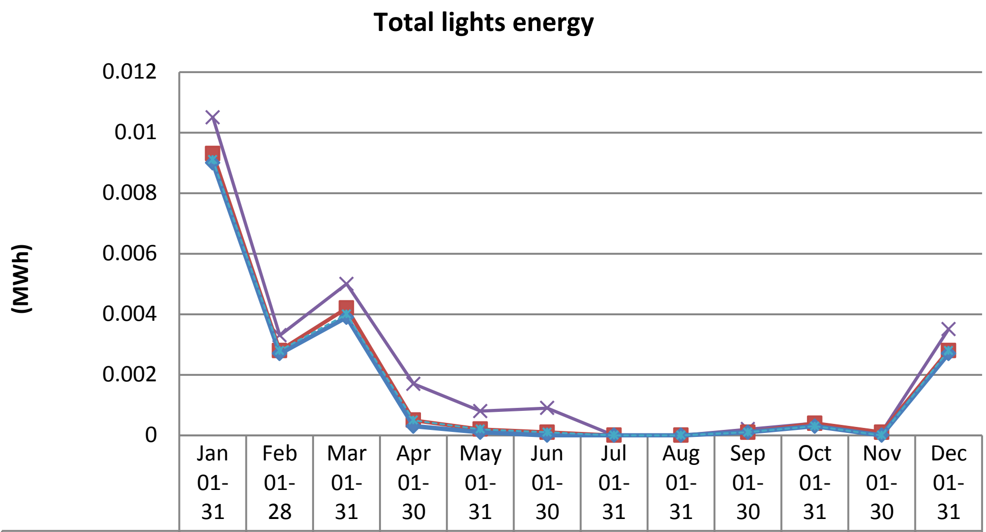
In figure (5.19) Values of room cooling plant showed the least in WWR 20 achieving 3.5771 MWh and 3.4853 MWh for the WWR 30 model.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
WWR 20	0	0.0074	0.1197	0.2951	0.6841	0.6862	0	0.052	0.8243	0.5505	0.2631	0.0027
WWR 30	0.0002	0.0093	0.1266	0.3063	0.7026	0.7023	0	0.0527	0.8392	0.5624	0.2723	0.0032
WWR 40	0.0005	0.0112	0.1339	0.3178	0.7207	0.7183	0	0.0534	0.8536	0.5738	0.2813	0.0036
596WD	0.0015	0.0184	0.1409	0.3192	0.6965	0.6869	0	0.0533	0.8265	0.5736	0.3148	0.0055

Figure (5.19) Room cooling plant sensible loads for WWR scenarios

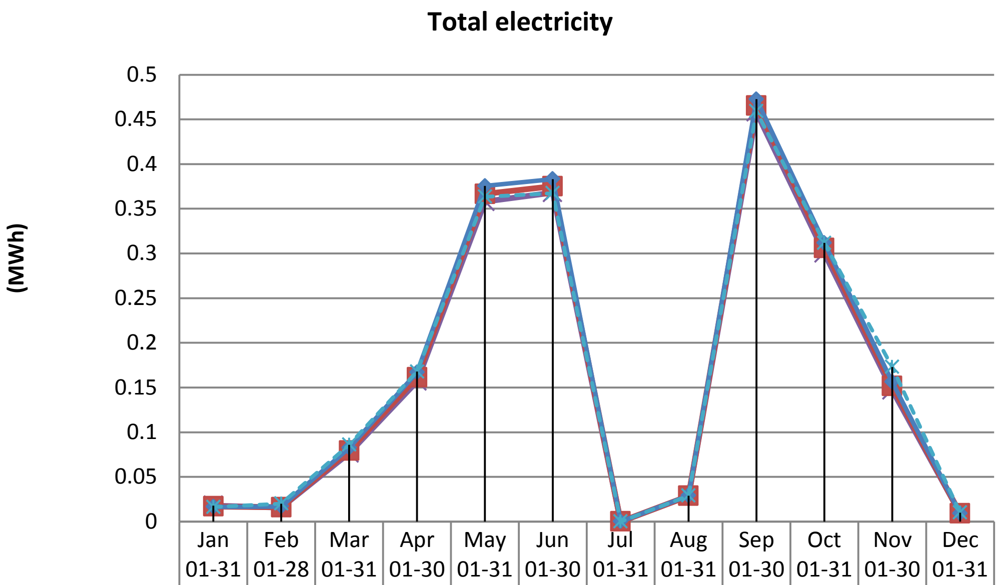
Values of models assessment in this chart were different than the previous order where WWR 40 had the minimum total lights energy as 0.0191 MWh while 596WD was the second and got 0.0199 MWh, after that, WWR 20 and WWR 30 were higher as displayed in figure (5.20).



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
WWR 20	0.0105	0.0033	0.005	0.0017	0.0008	0.0009	0	0	0.0002	0.0004	0.0001	0.0035
WWR 30	0.0093	0.0028	0.0042	0.0005	0.0002	0.0001	0	0	0.0001	0.0004	0.0001	0.0028
WWR 40	0.009	0.0027	0.0039	0.0003	0.0001	0	0	0	0.0001	0.0003	0	0.0027
596WD	0.0091	0.0028	0.004	0.0005	0.0002	0.0001	0	0	0.0001	0.0003	0	0.0028

Figure (5.20) Total lights energy for WWR scenarios

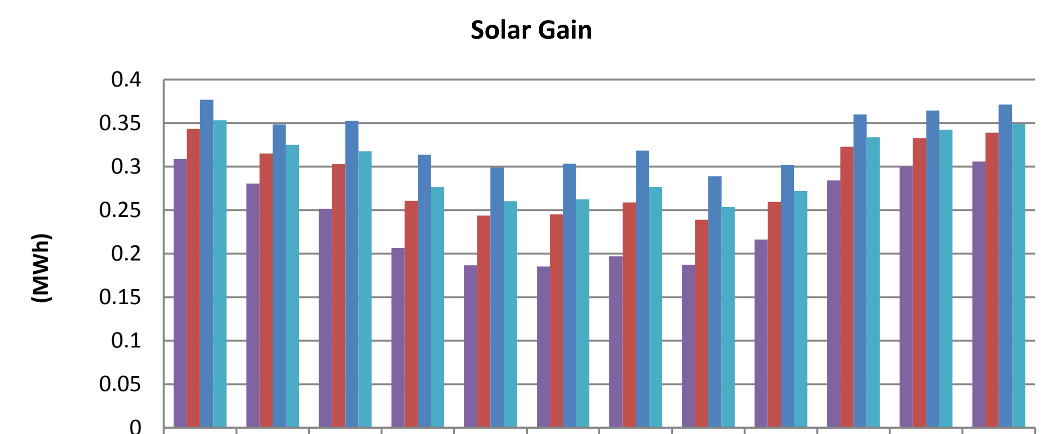
For total electricity in figure (5.21), WWR 30 and WWR 20 obtained the smallest values by achieving 1.9359 MWH and 1.9757 MWH respectively.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
WWR 20	0.018	0.0155	0.0765	0.1569	0.3579	0.3679	0	0.0284	0.458	0.3003	0.1471	0.0094
WWR 30	0.0168	0.016	0.0791	0.1613	0.3665	0.3751	0	0.0287	0.4654	0.3061	0.1517	0.0089
WWR 40	0.0165	0.0168	0.0824	0.1668	0.3755	0.3831	0	0.0291	0.4726	0.3118	0.1562	0.009
596WD	0.0163	0.0201	0.0859	0.1677	0.3634	0.3674	0	0.0291	0.4591	0.3117	0.1729	0.0101

Figure (5.21) Total electricity for WWR scenarios

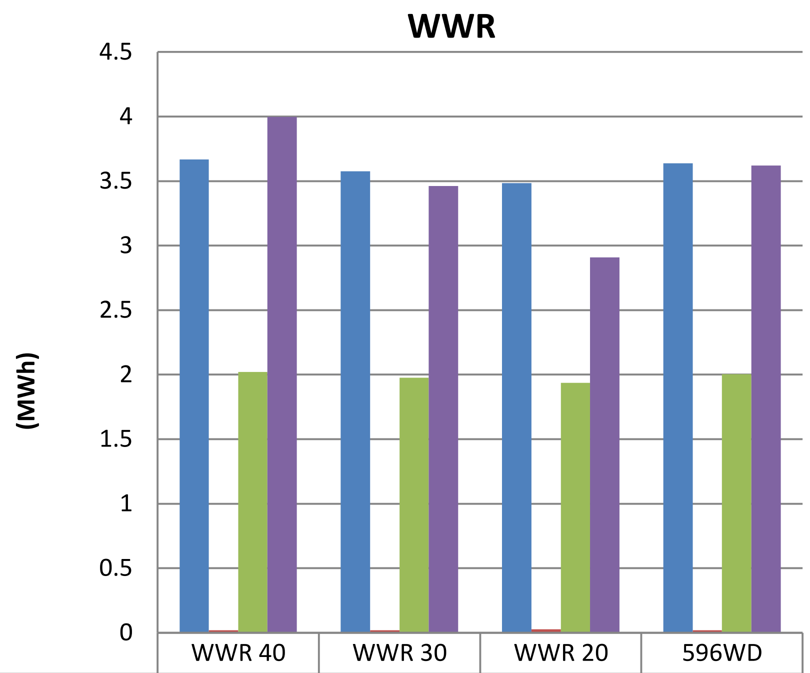
WWR 30 and WWR 20 have here again the least solar gain values which are 3.4615 MWh and 2.9087 respectively. But it shows in Figure (5.22) that the WWR 20 had a much lower value than the other 4 models.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
WWR 20	0.3088	0.2804	0.2513	0.2064	0.1866	0.1853	0.1971	0.187	0.2161	0.284	0.3	0.3057
WWR 30	0.3433	0.315	0.3027	0.2606	0.2436	0.2451	0.2587	0.2388	0.2596	0.3225	0.3326	0.339
WWR 40	0.3768	0.3485	0.3526	0.3133	0.2989	0.3033	0.3184	0.289	0.3018	0.3599	0.3643	0.3713
596WD	0.3533	0.3249	0.3175	0.2763	0.26	0.2624	0.2764	0.2537	0.2721	0.3336	0.342	0.3486

Figure (5.22) Solar gain values for the WWR scenarios

For the Window to wall ratio in figure (5.23), WWR 20 obtained 3.4853 MWh as the least room cooling plant load, while WWR 40 achieved the lowest value in total light energy as 0.0191 MWh. In the total electricity, WWR 20 was the least as it got 1.9359 MWh, as well it obtained 2.9087 MWh as the minimum solar gain value. That makes the Ratio WWR 20 as the optimum one between the other scenarios. However, with reference to the obtained values, there is a little impact of changing the WWR on the models consumption results. It's most probably due to the orientation of windows in the models which is located on the western side, and if it's tested on the other orientations or when the glazing has a low-E property it will show significant changes (Yang et al. 2015). They argued also that a range of 35-45% of WWR would be suitable to consume the least amount of energy in the room.



	WWR 40	WWR 30	WWR 20	596WD
Room cooling plant sens. load	3.6682	3.5771	3.4853	3.6371
Total lights energy	0.0191	0.0204	0.0263	0.0199
Total electricity	2.0198	1.9757	1.9359	2.0037
Solar gain	3.9982	3.4615	2.9087	3.6208

Figure (5.23) Total variables comparison between scenarios in WWR

5.5.2 Building construction materials

Estidama Regulations and concerns

Estidama is the Arabic translation for the term “sustainability”, and it’s been originated by Abu Dhabi authority which is targeting to improve urban fabric and cities concerning four main factors in sustainability economically, socially, culturally and environmentally. Estidama focused lately on developing codes which help the Middle East to achieve the best performance of building construction materials within Abu Dhabi Emirate. For that, Pearl rating system was introduced as design guidance to credit the project’s rating points according to the accomplished level, bearing in mind that Estidama has 5 levels of pearl that can be achieved. Many points are required to accomplish rating systems, but initially, the building should be evaluated through three rating phases beginning with design, then construction and finally operational. 1 Pearl and 2 Pearl rating systems will be used to assess the new classroom base case and investigate its impact on the room performance.

Dubai Municipality

DM was established in 1954 which was improved its activities since then to be one of the leading municipalities across the Emirates. Dubai planned strategic decisions for 2015 to have more friendly green buildings with higher specifications and more environmentally aware. DM regulations were used in this research for materials section to compare it with the other codes of Estidama.

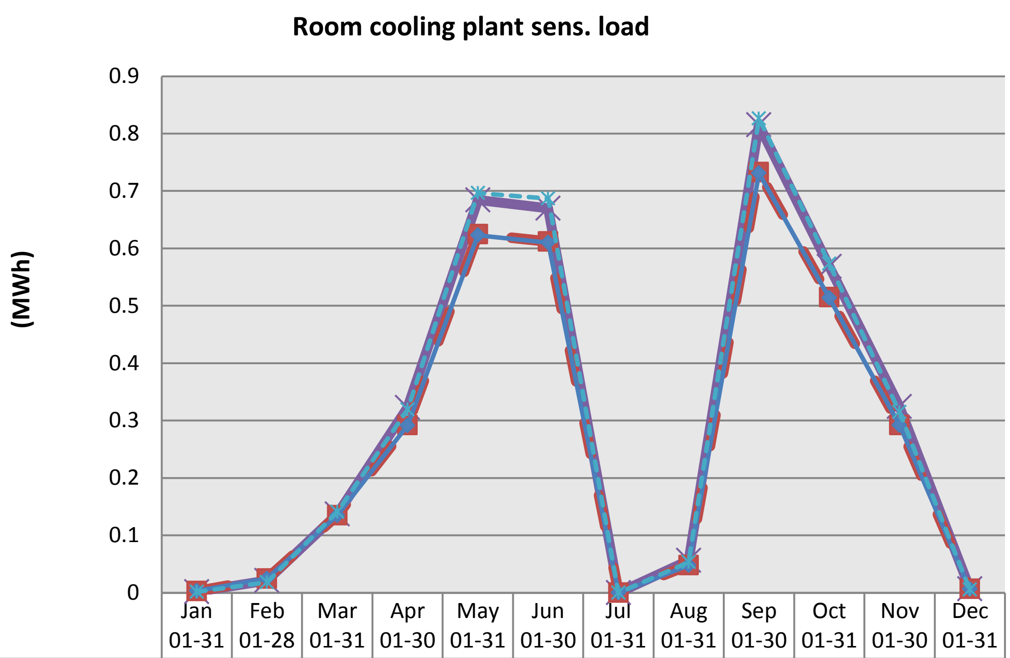
5.5.2.1 Walls

Wall thickness is taken into account where there is a big variation between the indoor and outdoor temperatures; that will avoid heat loss or gain and consequently less annual electrical loads. Thermal performance of a building should have a capability to effect on the R-values, and with reference to DM and Estidama codes, insulation materials will be applied which will help maintain IAQ; especially when walls occupy a big percentage of the total room area. Table (5.9) shows the layers of project construction for each of the regulations.

Table (5.9) Rating system requirements for wall U-values in building

Rating system/ U-Value W/m2-K	Dubai Municipality	Estidama 1 pearl	Estidama 2 pearl
Required value	0.57	0.320	0.290
Model value	0.4785	0.3198	0.2902

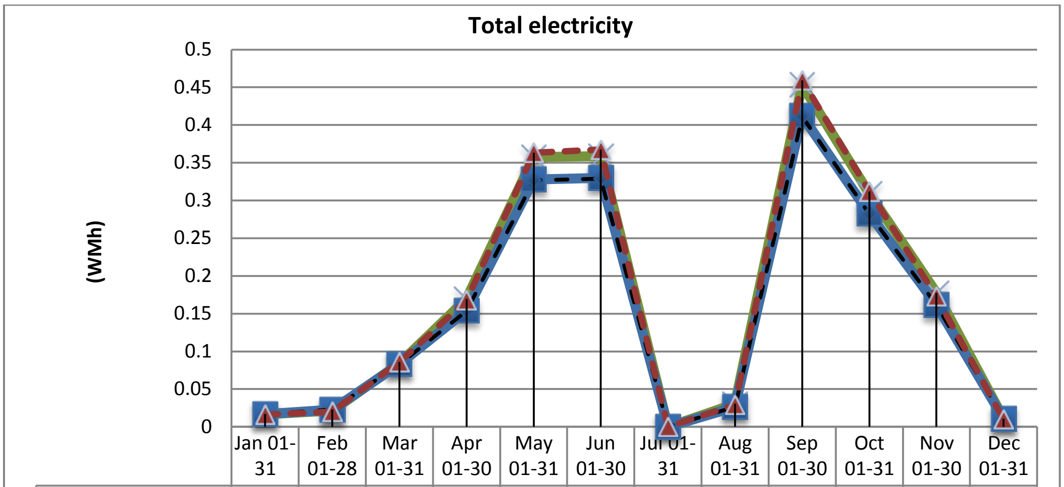
Values obtained in wall construction had the best performance in 2 Pearl – as 3.2787 MWh- and 1 Pearl which got second as 3.2856 MWh, and that results were much better than DM U-Value and the 596WD which less than both models by 9.6 % as displayed in figure (5.24).



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
Wall DM	0.0019	0.0213	0.1373	0.3226	0.6845	0.67	0	0.0563	0.8153	0.5687	0.3242	0.0069
Wall 1 Pearl	0.003	0.0243	0.1348	0.2919	0.6247	0.6119	0	0.0479	0.733	0.5151	0.2923	0.0066
Wall 2 Pearl	0.0031	0.0247	0.1347	0.2915	0.623	0.61	0	0.0479	0.7309	0.514	0.2923	0.0067
596WD	0.0015	0.0184	0.1409	0.3192	0.6965	0.6869	0	0.0533	0.8265	0.5736	0.3148	0.0055

Figure (5.24) Room cooling plant sensible load for wall U-Value scenarios

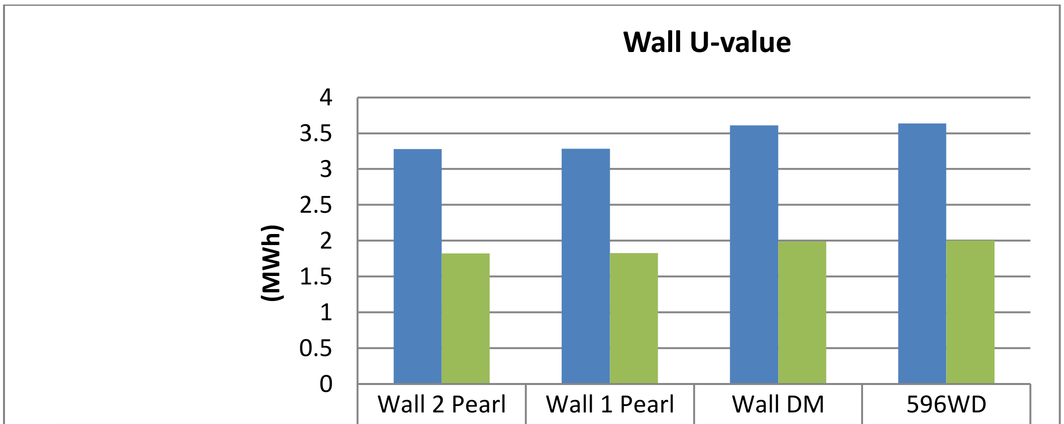
Results gained by 2 Pearl were the least –which was 1.8243 MWh- and in 1 Pearl it was the second at recorded 1.8277 MWh annually. Total electricity reached its peak in September for all cases as shown in figure (5.25), and that was due to the summer high temperatures which required more HVAC consumption, however, the use of the rating system materials reduced electrical loads.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
Wall DM	0.0164	0.0215	0.0841	0.1694	0.3575	0.3589	0	0.0306	0.4535	0.3093	0.1776	0.0108
Wall 1 Pearl	0.017	0.023	0.0829	0.1539	0.3276	0.3299	0	0.0264	0.4123	0.2825	0.1616	0.0106
Wall 2 Pearl	0.017	0.0231	0.0828	0.1538	0.3267	0.3289	0	0.0263	0.4113	0.2819	0.1616	0.0108
596WD	0.0163	0.0201	0.0859	0.1677	0.3634	0.3674	0	0.0291	0.4591	0.3117	0.1729	0.0101

Figure (5.25) Total electricity values for wall U-Value scenarios

After changing building construction materials, they were evaluated according to the rating systems mentioned previously in this chapter. In figure (5.26), room cooling plant after changing the walls according to the given U-Values, the minimum load was in 2 Pearl achieving 3.2787 MWh. The most saving in total lights energy was 2 Pearl which got 1.8243 MWh, and the solar gain values are not going to change, because we are changing the wall or roof U-value, but the glass maintains the same. Eventually, 2 Pearl is considered the best model for wall U-Value scenario.



	Wall 2 Pearl	Wall 1 Pearl	Wall DM	596WD
Room cooling plant sens. load	3.2787	3.2856	3.609	3.6371
Total electricity	1.8243	1.8277	1.9896	2.0037

Figure (5.26) Total variables comparison between scenarios in Wall U-Value

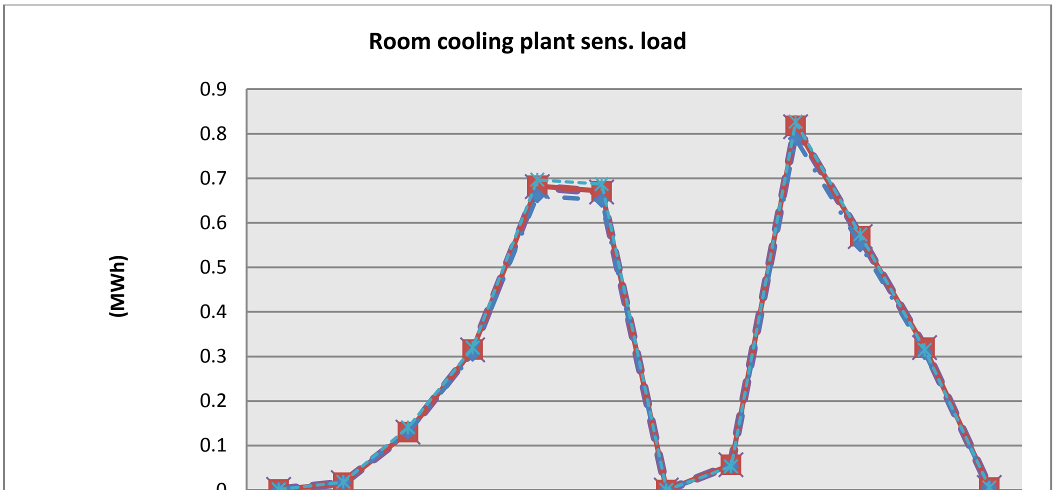
5.5.2.2 Roof

This exposed area to the direct solar radiation has many features which are affected by the building purpose. Roof materials should protect the indoor space from the natural factors, and insulation choice can prevent from undesired heat loss or gain. Reflective materials have impact on the annual cooling loads, and all of these parameters will be gauged in the classroom while using the given U-Values which are provided from the main 3 rating systems as listed in Table (5.10).

Table (5.10) Rating system requirements for roof U-values in building

Rating system/ U-Value W/m2-K	Dubai Municipality	Estidama 1 pearl	Estidama 2 pearl
Required value	0.30	0.140	0.120
Model value	0.2474	0.1493	0.1200

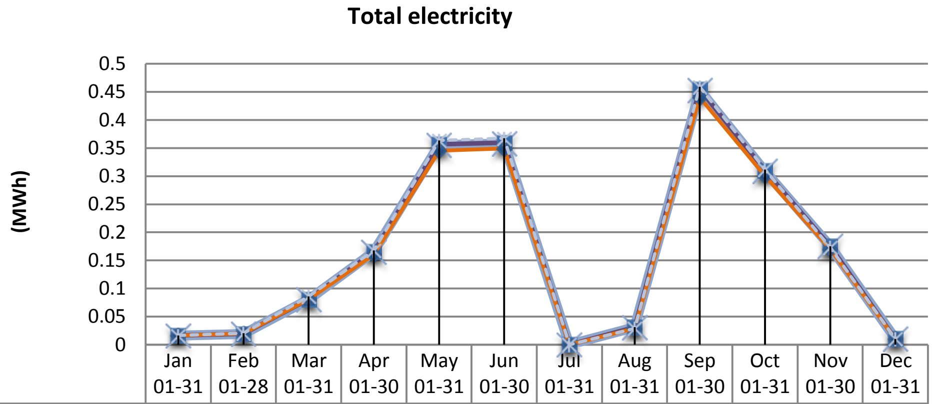
Roof U value performance in the room cooling plant was variable through all months. Total cooling loads achieved in Roof DM 3.4735 MWh and 3.577 MWh in the 2 Pearl scenario shown in figure (5.27).



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
Roof 2 Pearl	0.0012	0.0164	0.1297	0.3143	0.6807	0.6689	0	0.0569	0.8151	0.5685	0.3194	0.0058
Roof 1 Pearl	0.0012	0.0164	0.1302	0.3149	0.6826	0.6709	0	0.0569	0.8171	0.5696	0.3195	0.0057
Roof DM	0.0016	0.018	0.1304	0.3051	0.6606	0.6507	0	0.0528	0.7889	0.5511	0.3086	0.0056
596WD	0.0015	0.0184	0.1409	0.3192	0.6965	0.6869	0	0.0533	0.8265	0.5736	0.3148	0.0055

Figure (5.27) Room cooling plant sensible load for roof U-Value scenarios

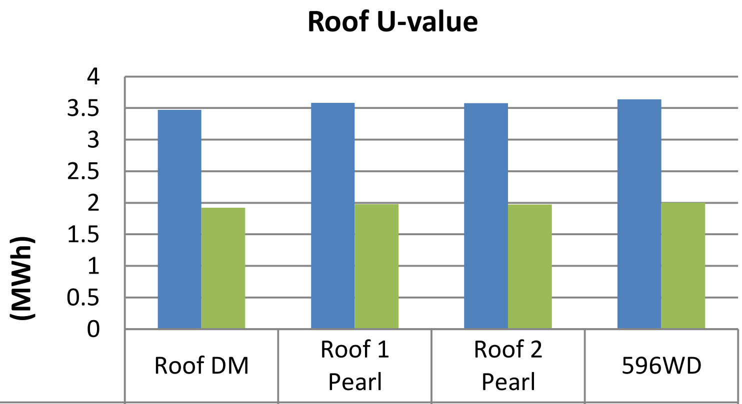
It shows that figure (5.28) indicates the least total electricity by the DM roof system which obtained 1.922 MWh, and then the 2 Pearl which got 1.9737 MWh. Practically, values were close, and small alteration was found by the aid of excel charts which added the values of months for all models, and that leads to having DM as the minimum value in total electricity.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
Roof 2 Pearl	0.0162	0.0191	0.0803	0.1652	0.3556	0.3584	0	0.0309	0.4534	0.3092	0.1752	0.0102
Roof 1 Pearl	0.0161	0.0191	0.0806	0.1655	0.3566	0.3594	0	0.0309	0.4544	0.3098	0.1752	0.0101
Roof DM	0.0164	0.0199	0.0807	0.1606	0.3455	0.3493	0	0.0288	0.4403	0.3005	0.1698	0.0101
596WD	0.0163	0.0201	0.0859	0.1677	0.3634	0.3674	0	0.0291	0.4591	0.3117	0.1729	0.0101

Figure (5.28) Total electricity loads for roof U-Value scenarios

Figure (5.29) presents the performance of roof U-Value which was assessed and resulted that the minimum cooling plant was in Roof DM as 3.4735 MWh. After evaluating the four variables in these models, it turns that Roof DM final results calculated the finest energy saving outcome.



	Roof DM	Roof 1 Pearl	Roof 2 Pearl	596WD
Room cooling plant sens. load	3.4735	3.5851	3.577	3.6371
Total electricity	1.922	1.9776	1.9737	2.0037

Figure (5.29) Total variables comparison between scenarios in roof U-Value

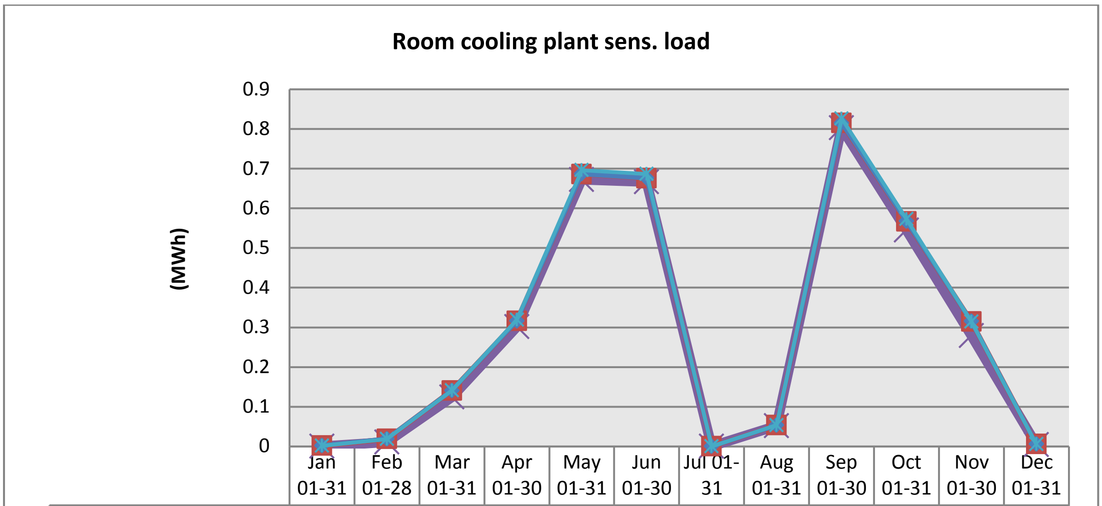
5.5.2.3 Window Glazing

Controlling solar gain through windows is the key element in buildings where glass splits the exterior environment from the interior. Solar Heat Gain Coefficient (SHGC) is an important factor that has a direct impact, especially in hot regions. González and Fiorito (2015) consider that a value of 0.75 is acceptable for SHGC for the external windows. Transparency of the glass has an influence on solar absorbance and the transmittance of heat inside the room, and therefore, all selected classrooms have a transparent glazing which will be measured by IES according to the U-value. Air and light exchange occurs through windows, and typically at classrooms glazing area and ratio should be applied according to the requirements of the function in the room. Operation of windows plays a role in refreshing the indoor space and improve air intake, but this research focuses precisely on the size and shape of classroom openings. Table (5.11) shows the required U-values from the rating systems, and the construction layers prepared in IES for modeling.

Table (5.11) Rating system requirements for glazing U-values in building

Rating system/ U-Value W/m2-K	Dubai Municipality	Estidama 1 pearl	Estidama 2 pearl
Required value	3.28	2.200	1.900
Model value	3.057	2.061	1.734

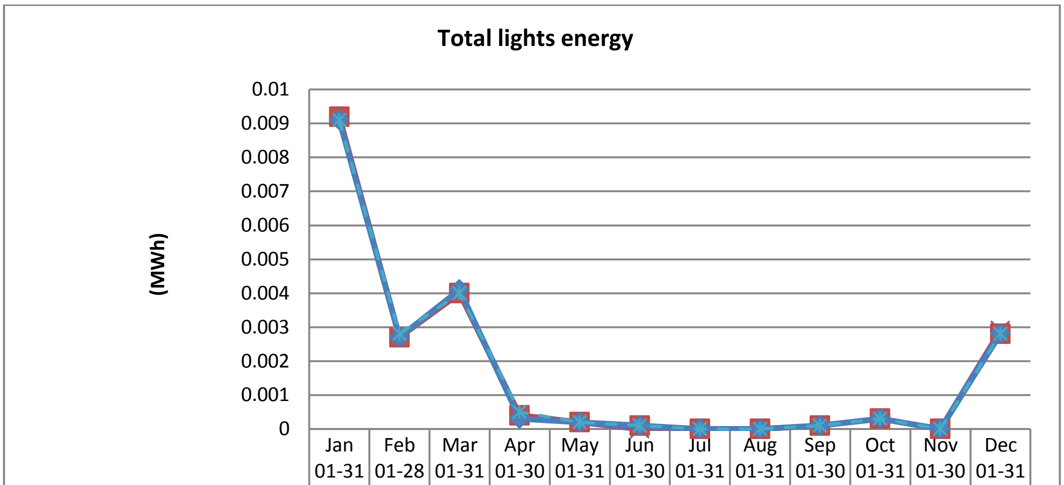
Changing glazing U-Value worked the best with DM rating system which obtained the lowest –with a value of 3.4577 MWh- among the other models. Figure (5.30) shows that 1 Pearl and 2 Pearl had results alike which were 3.5974 MWh and 3.5946 MWh respectively. 596WD had the highest value in this assessment.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
Window UV DM	0.0002	0.0104	0.124	0.3013	0.6721	0.6671	0	0.052	0.8029	0.5449	0.2787	0.0042
Window UV 2 Pearl	0.0016	0.0186	0.1405	0.3158	0.6863	0.6759	0	0.053	0.8152	0.5672	0.3148	0.0056
Window UV 1 Pearl	0.0017	0.0187	0.1407	0.316	0.6867	0.6762	0	0.053	0.8156	0.5677	0.3153	0.0057
596WD	0.0015	0.0184	0.1409	0.3192	0.6965	0.6869	0	0.0533	0.8265	0.5736	0.3148	0.0055

Figure (5.30) Room cooling plant sensible load for glazing U-value scenarios

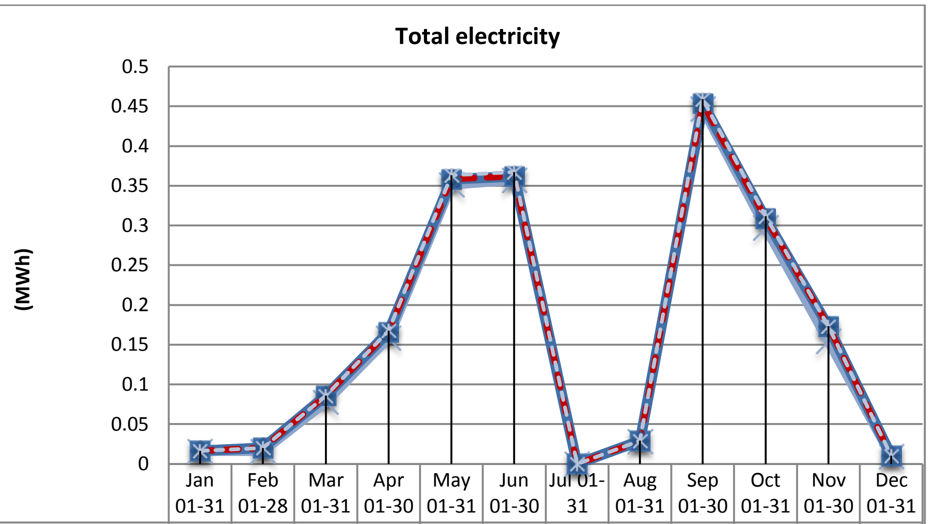
Evaluation in total lights energy indicated the same results for DM, 596WD and 2 Pearl as 0.0199 MWh while it dropped one value with 1 Pearl having 0.0198 MWh as displayed in figure (5.31). This similarity is predictable to be due to the similar building construction material of glass which will permit the same amounts of natural daylight to pass through the class, and the artificial lights will work the same to maintain the desired lux value.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
Window UV DM	0.0092	0.0027	0.004	0.0004	0.0002	0	0	0	0.0001	0.0003	0	0.0029
Window UV 2 Pearl	0.0092	0.0027	0.004	0.0004	0.0002	0.0001	0	0	0.0001	0.0003	0	0.0028
Window UV 1 Pearl	0.0091	0.0027	0.0041	0.0003	0.0002	0.0001	0	0	0.0001	0.0003	0	0.0028
596WD	0.0091	0.0028	0.004	0.0005	0.0002	0.0001	0	0	0.0001	0.0003	0	0.0028

Figure (5.31) Total lights energy for glazing U-value scenarios

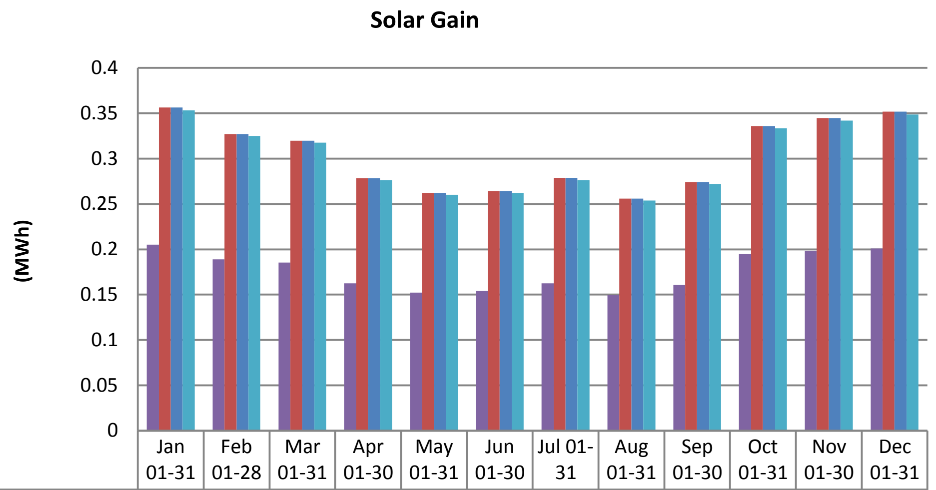
Outcomes of total electricity clarify that Window U-value for DM is the minimum with a value of 1.9147 MWh, and the second system is 2 Pearl which got 1.9823 MWh. However, results in figure (5.32) for the four models don't have a considerable gap of variation which can be assumed due to the similarity in regulations values of rating systems.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
Window UV DM	0.0162	0.0162	0.0775	0.1587	0.3512	0.3575	0	0.0284	0.4472	0.2974	0.1549	0.0095
Window UV 2 Pearl	0.0165	0.02	0.0857	0.166	0.3584	0.3619	0	0.0289	0.4534	0.3086	0.1729	0.0102
Window UV 1 Pearl	0.0164	0.0201	0.0859	0.166	0.3586	0.3621	0	0.0289	0.4536	0.3088	0.1731	0.0102
596WD	0.0163	0.0201	0.0859	0.1677	0.3634	0.3674	0	0.0291	0.4591	0.3117	0.1729	0.0101

Figure (5.32) Total electricity for glazing U-value scenarios

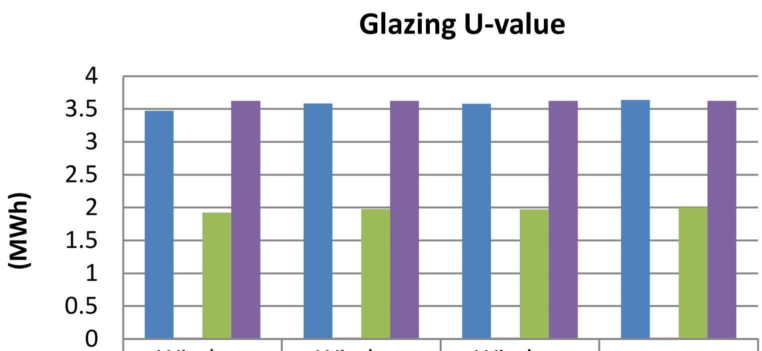
In figure (5.33), Window U-value DM obtained a remarkable minimum value compared to the other classroom models. This scenario got 2.1146 MWh which is 1.4 MWh much less the other 3 models which makes it the least solar gainer in this stage.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
Window UV DM	0.2053	0.1888	0.1854	0.1624	0.1522	0.154	0.1624	0.1493	0.1606	0.1949	0.1983	0.2011
Window UV 2 Pearl	0.3564	0.3273	0.3199	0.2786	0.2622	0.2645	0.2787	0.2558	0.2741	0.3359	0.3448	0.3518
Window UV 1 Pearl	0.3564	0.3273	0.3199	0.2786	0.2622	0.2645	0.2787	0.2558	0.2741	0.3359	0.3448	0.3518
596WD	0.3533	0.3249	0.3175	0.2763	0.26	0.2624	0.2764	0.2537	0.2721	0.3336	0.342	0.3486

Figure (5.33) Solar gain for glazing U-value scenarios

In the glazing U-Value, the impact on the models was clear 1 Pearl which obtained 3.4735 MWh, and it gained the second value of total lights energy –which matches 596WD result- and it was the least also in the total electricity by achieving 1.922 MWh. With reference to figure (5.34), it appears that UV 1 Pearl was the first best room cooling sensible, whereas in total lights energy it was the second –also equal to 596WD- in small fraction, moreover for total electricity it was the least consuming glazing system. Add to that that the four models had identical result in the solar gain which is not useful to compare. Therefore, the overall results nominate window UV 1 Pearl to be the best case among the others.



	Window UV 1 Pearl	Window UV 2 Pearl	Window UV DM	596WD
Room cooling plant sensible load	3.4735	3.5851	3.577	3.6371
Total lights energy	0.0199	0.0198	0.02	0.0199
Total electricity	1.922	1.9776	1.9737	2.0037
Solar gain	3.6208	3.6208	3.6208	3.6208

Figure (5.34) Total variables comparison between scenarios in glazing U-Value

5.5.3 Window Aspects

5.5.3.1 Wall Height to width ratio (WHWR)

It's crucial to know what size of window will serve the need of the space where proportions of the opening should be designed in relation to the classroom's standards. Appropriate selection of height/width ratio would be significant when it provides a proper daylighting and a good outdoor view. In this section, three ratios are proposed to assess their values with the other factors.

(1/2)	(1/1)	(2/1)
2 windows (1.47H x 2.94W)m each	2 windows (2.09H x 2.09W)m each	4 windows (2.08H x 1.04W)m each

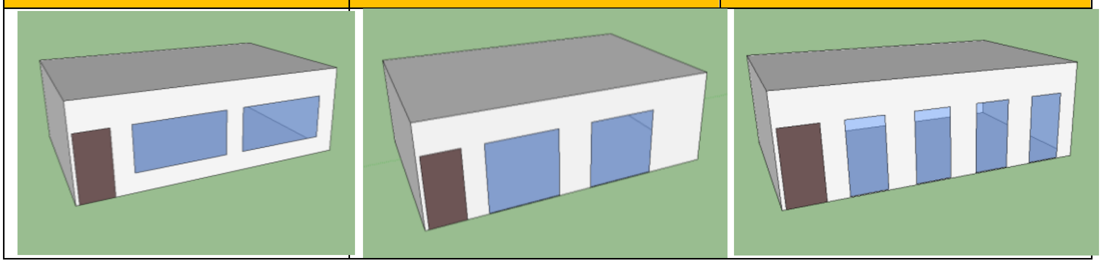
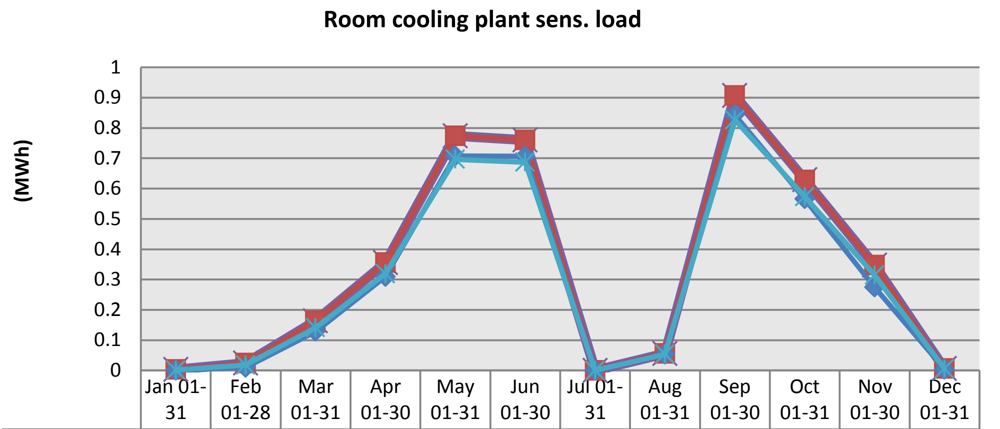


Figure (5.35) Height to width ratio in 3 scenarios (Author)

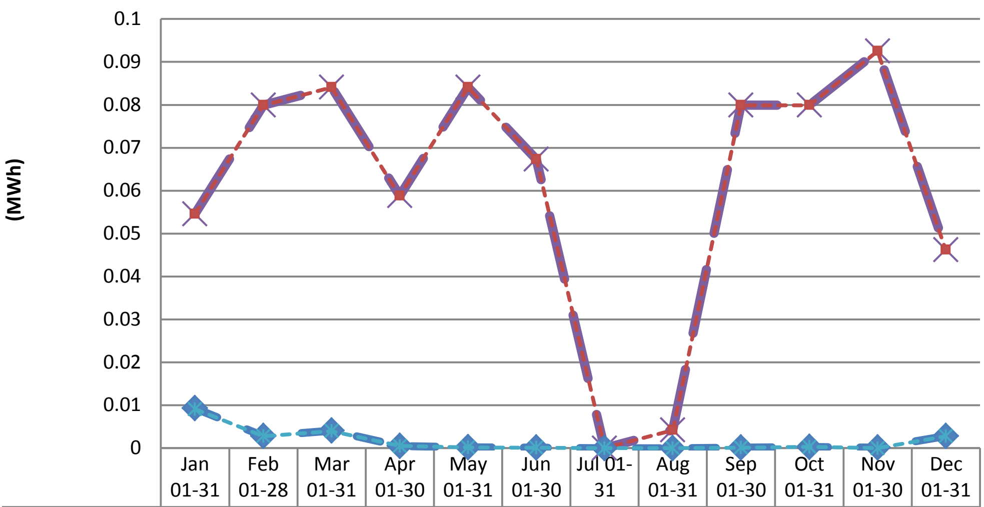
For the room cooling plant in Height to width ratio shown in figure (5.36), the room ratio 1/2 achieved the lowest value as 3.6017 MWh and secondly 596WD which got 3.6371 MWh. Other ratios –of 1/1 and 2/1- where higher than this range and will not be included in comparison.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
HW 1/1	0.0027	0.0242	0.1638	0.3556	0.7742	0.7602	0	0.0561	0.9068	0.6287	0.3471	0.006
HW 2/1	0.0026	0.0241	0.1635	0.3553	0.7738	0.7599	0	0.0561	0.9064	0.6284	0.3469	0.006
HW 1/2	0.0003	0.0098	0.1286	0.3094	0.7075	0.7066	0	0.0529	0.8431	0.5654	0.2748	0.0033
596WD	0.0015	0.0184	0.1409	0.3192	0.6965	0.6869	0	0.0533	0.8265	0.5736	0.3148	0.0055

Figure (5.36) Room cooling plant sensible load for glazing WHWR scenarios

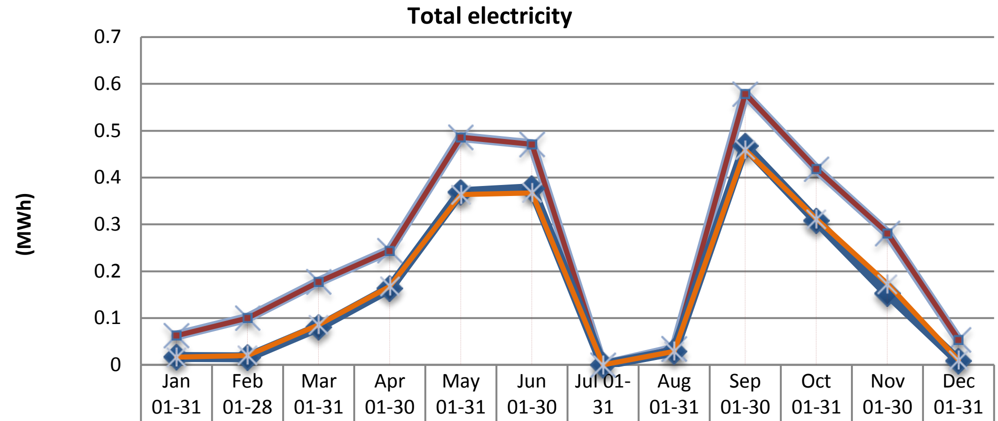
In figure (5.37), total lights energy recorded a great variation between 2 groups of results where 596WD and 1/2 had low values -0.0199 and 0.0204 MWh in order- and on the other hand, 1/1 and 2/1 obtained high values –having 0.7314 MWh for both- and that is a significant increase in total consumption of lights energy that will be considered later on. For figure (5.37), WHWR 1/1 and WHWR 2/1 got the same results, as well as the scenarios 596WD and WHWR 1/2 which consumed equal values, that’s why they seem like overlapping in the graph, and this equality will be reflected further more in selecting the best case among these scenarios.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
HW 1/1	0.0546	0.0799	0.0841	0.0588	0.0841	0.0673	0	0.0042	0.0799	0.0799	0.0925	0.0462
HW 2/1	0.0546	0.0799	0.0841	0.0588	0.0841	0.0673	0	0.0042	0.0799	0.0799	0.0925	0.0462
HW 1/2	0.0093	0.0028	0.0041	0.0005	0.0002	0.0001	0	0	0.0001	0.0003	0.0001	0.0028
596WD	0.0091	0.0028	0.004	0.0005	0.0002	0.0001	0	0	0.0001	0.0003	0	0.0028

Figure (5.37) Total lights energy for glazing WHWR scenarios

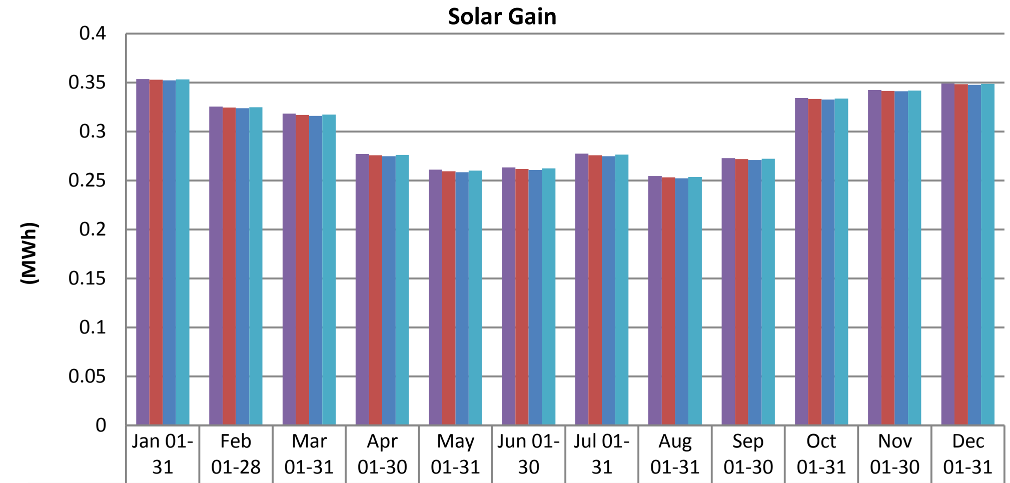
HW 1/2 obtained a total electricity of 1.9879 MWh as the first minimum value, and then was the 596WD which had 2.0037 MWh. In figure (5.38), the other 2 scenarios are higher than 596WD which gained a 0.9 MWh.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
HW 1/1	0.0626	0.1002	0.1775	0.2443	0.4862	0.4713	0	0.0347	0.579	0.4188	0.2815	0.0538
HW 2/1	0.0626	0.1001	0.1774	0.2441	0.486	0.4711	0	0.0347	0.5788	0.4187	0.2814	0.0538
HW 1/2	0.0168	0.0162	0.0801	0.1628	0.369	0.3772	0	0.0288	0.4674	0.3077	0.1529	0.009
596WD	0.0163	0.0201	0.0859	0.1677	0.3634	0.3674	0	0.0291	0.4591	0.3117	0.1729	0.0101

Figure (5.38) Total electricity for glazing WHWR scenarios

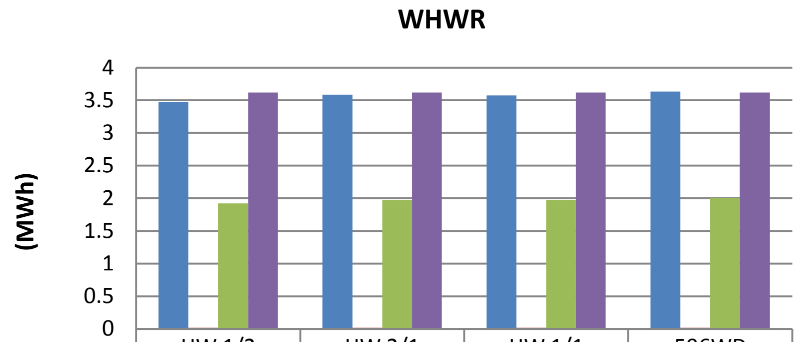
There is no major distinction between the results of solar gain in the window height to width ratios. Yet, the least value was obtained in ratio 1/2 which had 3.6057 MWh. Second lowest result was in the 2/1 ratio model which got 3.6152 MWh as it appears in figure (5.39).



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
HW 1/1	0.3538	0.3255	0.3184	0.2772	0.261	0.2634	0.2775	0.2546	0.2729	0.3343	0.3426	0.3492
HW 2/1	0.3529	0.3246	0.317	0.2758	0.2595	0.2619	0.2758	0.2532	0.2718	0.3333	0.3417	0.3483
HW 1/2	0.3523	0.324	0.3161	0.2748	0.2584	0.2608	0.2747	0.2523	0.271	0.3326	0.3411	0.3477
596WD	0.3533	0.3249	0.3175	0.2763	0.26	0.2624	0.2764	0.2537	0.2721	0.3336	0.342	0.3486

Figure (5.39) Solar gain for glazing WHWR scenarios

Simulation of windows aspects was initiated by height to width ratio. Room cooling plant load was the lowest in HW 1/2 which got 3.4735 MWh. Total lights energy shown in figure (5.40) had the least in HW 2/1 as 0.0198 MWh, after that was the HW 1/2 and 596WD which got 0.0199 MWh. The minimum level of total electricity was obtained by HW 1/2 that got 1.922 MWh. The issue of solar gain value is repeated here to be the same value for all models. For that, the model HW 1/2 is chosen to be the least consuming model in height to width ratio amongst the others.



	HW 1/2	HW 2/1	HW 1/1	596WD
Room cooling plant sensible load	3.4735	3.5851	3.577	3.6371
Total lights energy	0.0199	0.0198	0.02	0.0199
Total electricity	1.922	1.9776	1.9737	2.0037
Solar gain	3.6208	3.6208	3.6208	3.6208

Figure (5.40) Total variables comparison between scenarios in WHWR ratio

5.5.3.2 Glazing position

Sunlight hits the glass of classroom along the day time which makes the room heated and naturally lit. Position of glazing in the building can be externally flush, internally flush or fixed in the middle of the wall section. That has an effect on the incident solar radiation in the space and when the wall has a deep recess it would decrease the heating values in the room.

Flush outside	Middle fixed	Flush inside

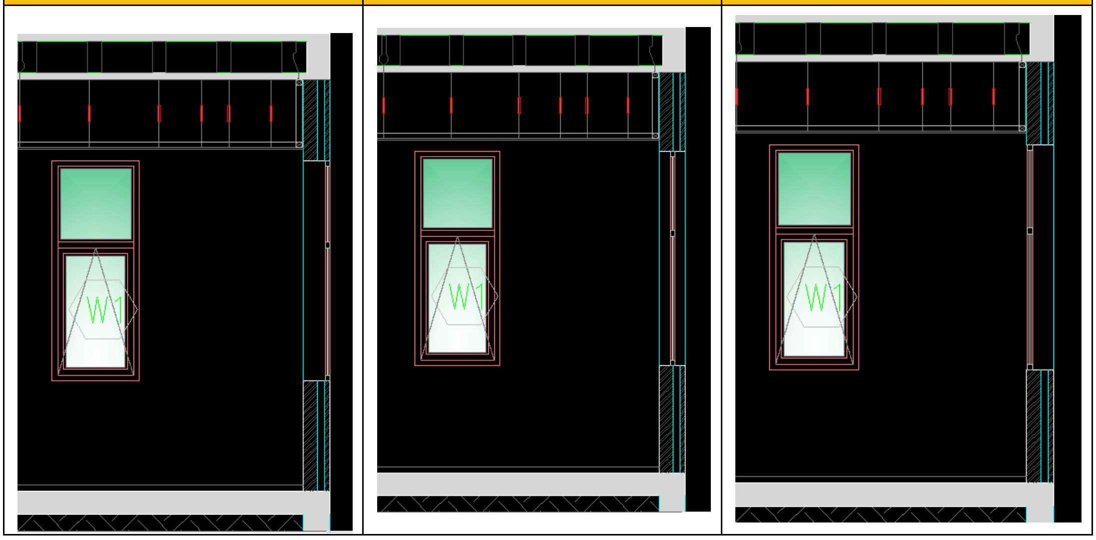
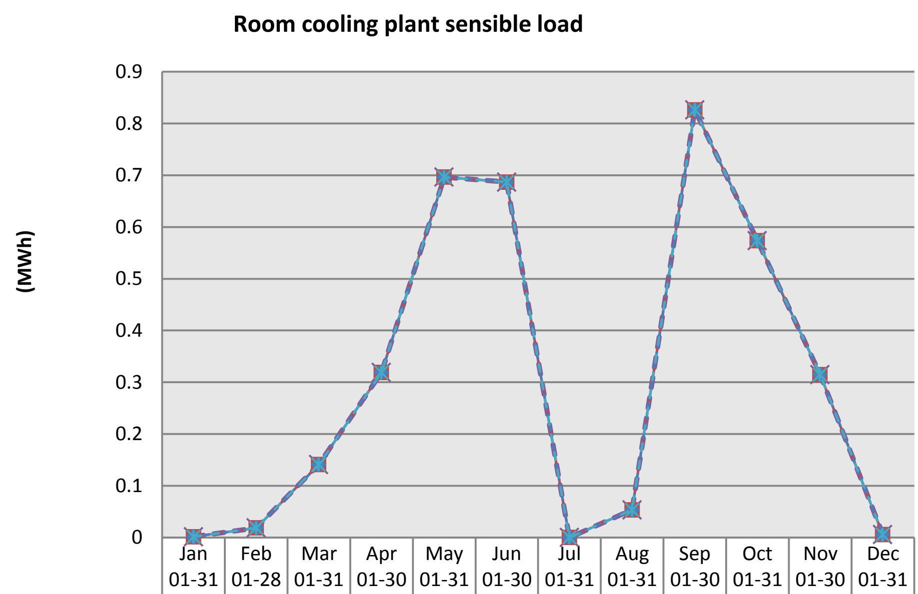


Figure (5.41) Three glazing position scenarios- AutoCAD (Author)

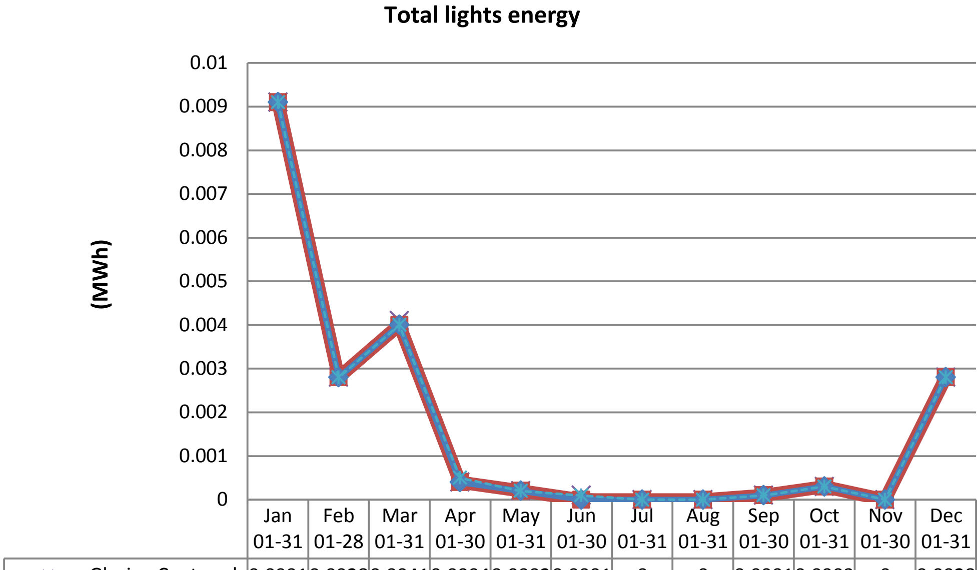
For room cooling plant shown in figure (5.42), results of assessment after changing the position of the glass where not highly effective, not only on the cooling plant values, but on all criteria of evaluation in this section. 3 models have got the same values which are the glazing recessed, glazing centred and 596WD and the result was 3.6371 MWh, also the fourth model –the glazing projected- got 3.637 MWh which is only 0.0001 MWh less than the others.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
Glazing Centered	0.0015	0.0184	0.141	0.3192	0.6965	0.6869	0	0.0533	0.8265	0.5735	0.3148	0.0055
Glazing Projected	0.0015	0.0184	0.1409	0.3191	0.6965	0.6869	0	0.0533	0.8265	0.5735	0.3148	0.0055
Glazing Recessed	0.0015	0.0184	0.1409	0.3191	0.6965	0.6869	0	0.0533	0.8265	0.5736	0.3148	0.0055
596WD	0.0015	0.0184	0.1409	0.3192	0.6965	0.6869	0	0.0533	0.8265	0.5736	0.3148	0.0055

Figure (5.42) Room cooling plant sensible load values for the glazing position scenarios

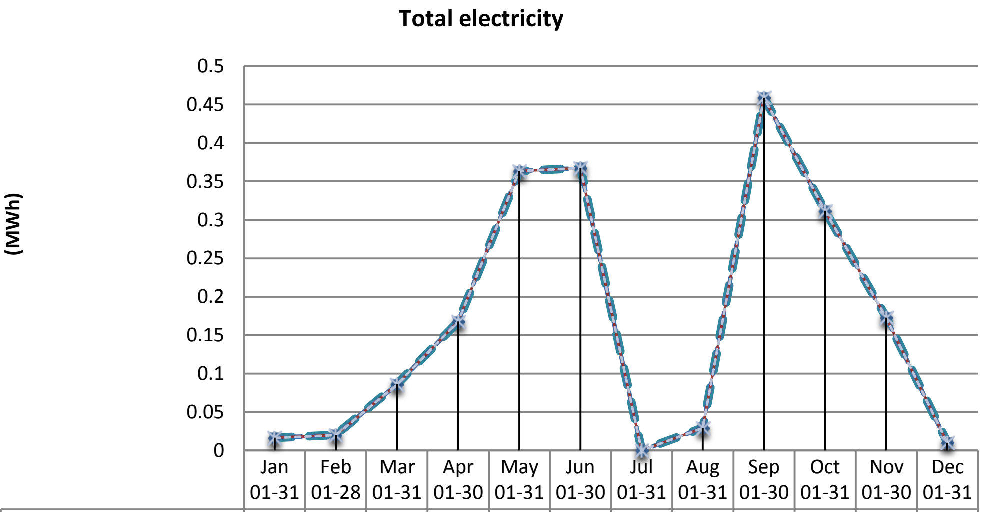
Total lights energy values were achieved the same for all scenarios. The result obtained here –as 0.0199 MWh- should be highlighted; due to its duplication in 596WD and the other models, and that means that these attempts didn't provide any required drop in lights energy.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
Glazing Centered	0.0091	0.0028	0.0041	0.0004	0.0002	0.0001	0	0	0.0001	0.0003	0	0.0028
Glazing Projected	0.0091	0.0028	0.004	0.0004	0.0002	0	0	0	0.0001	0.0003	0	0.0028
Glazing Recessed	0.0091	0.0028	0.004	0.0004	0.0002	0	0	0	0.0001	0.0003	0	0.0028
596WD	0.0091	0.0028	0.004	0.0005	0.0002	0.0001	0	0	0.0001	0.0003	0	0.0028

Figure (5.43) Total lights energy values for the glazing position scenarios

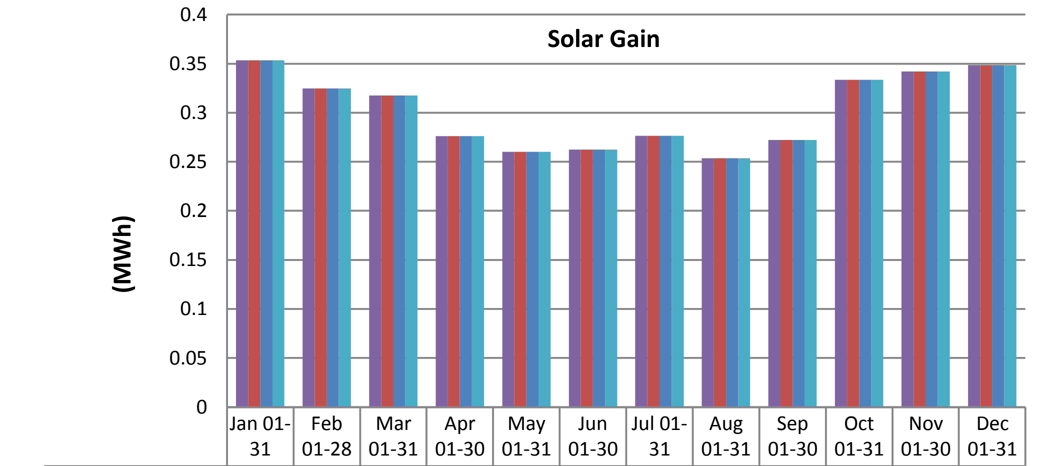
Total electricity was having 2 similar models having same values as shown in figure (5.44). Glazing recessed and glazing projected got 2.0036 MWh while glazing centred and 596WD got 2.0037 MWh where the difference is fractional also as 0.1 KWh only.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
Glazing Centered	0.0164	0.02	0.086	0.1676	0.3635	0.3674	0	0.0291	0.4591	0.3117	0.1729	0.0101
Glazing Projected	0.0164	0.0201	0.0859	0.1676	0.3635	0.3674	0	0.0291	0.4591	0.3117	0.1729	0.0101
Glazing Recessed	0.0164	0.02	0.0859	0.1676	0.3635	0.3674	0	0.0291	0.4591	0.3117	0.1729	0.0101
596WD	0.0163	0.0201	0.0859	0.1677	0.3634	0.3674	0	0.0291	0.4591	0.3117	0.1729	0.0101

Figure (5.44) Total electricity values for the glazing position scenarios

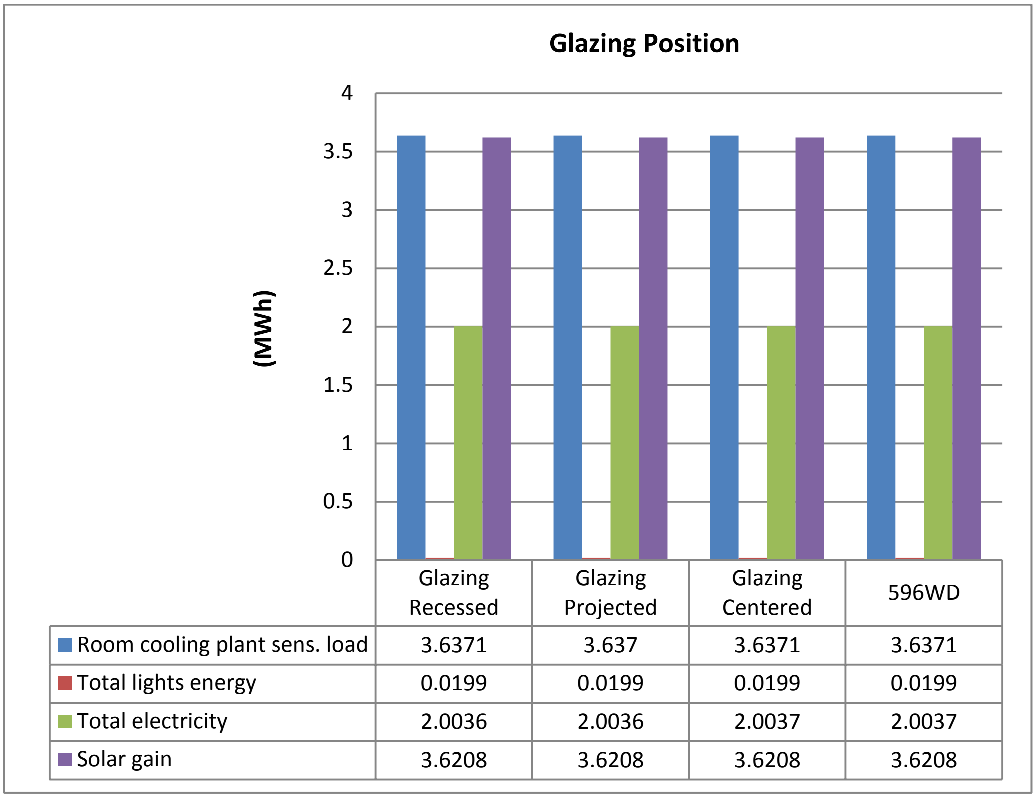
Solar gain for glazing position results in figure (5.45) show identical outcomes for all models which gained 3.6208 MWh. And these values will be considered in terms of its incapability to reduce any of the solar gain values, and the other values of comparison along the charts analyzed above.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
Glazing Centered	0.3533	0.3249	0.3175	0.2763	0.26	0.2624	0.2764	0.2537	0.2721	0.3336	0.342	0.3486
Glazing Projected	0.3533	0.3249	0.3175	0.2763	0.26	0.2624	0.2764	0.2537	0.2721	0.3336	0.342	0.3486
Glazing Recessed	0.3533	0.3249	0.3175	0.2763	0.26	0.2624	0.2764	0.2537	0.2721	0.3336	0.342	0.3486
596WD	0.3533	0.3249	0.3175	0.2763	0.26	0.2624	0.2764	0.2537	0.2721	0.3336	0.342	0.3486

Figure (5.45) Solar gain values for the glazing position scenarios

It was discussed previously that the glazing position in the detailed charts did not achieve remarkable values that can have an impact on energy saving. Values in figure (5.46) show that the projected glazing which is flush to outside had less room cooling plant recording 3.637 MWh but it only reduced 0.1 KWh between the others. For the total electricity, projected glazing and the recessed one had 2.0036 MWh while the centred glazing and 596WD as 2.0037 MWh. In the total lights energy, all values were the same as 0.0199 MWh and also the solar gain which was 3.6208 MWh for all models. With reference to the numbers and calculations, the projected glazing which is flush outside the classroom should be considered as the most appropriate scenario between the other glazing types; however, when looking at the very similar and identical values, it seems that no many obligations can be derived from this aspect.



	Glazing Recessed	Glazing Projected	Glazing Centered	596WD
Room cooling plant sens. load	3.6371	3.637	3.6371	3.6371
Total lights energy	0.0199	0.0199	0.0199	0.0199
Total electricity	2.0036	2.0036	2.0037	2.0037
Solar gain	3.6208	3.6208	3.6208	3.6208

Figure (5.46) Total variables comparison between scenarios in glazing position

5.6 Optimum case setup and simulation

Each of the critical building components were already discussed, analyzed and compared with their variable aspects in terms of energy saving and reduction of electrical artificial lights. The aim here is to combine the best of each aspect to sum up the finest educational classroom which is supposed to fulfill the intentions to reduce the undesired artificial lights and the values of cooling loads, also the total electricity energy which will consequently drop when less lighting is used.

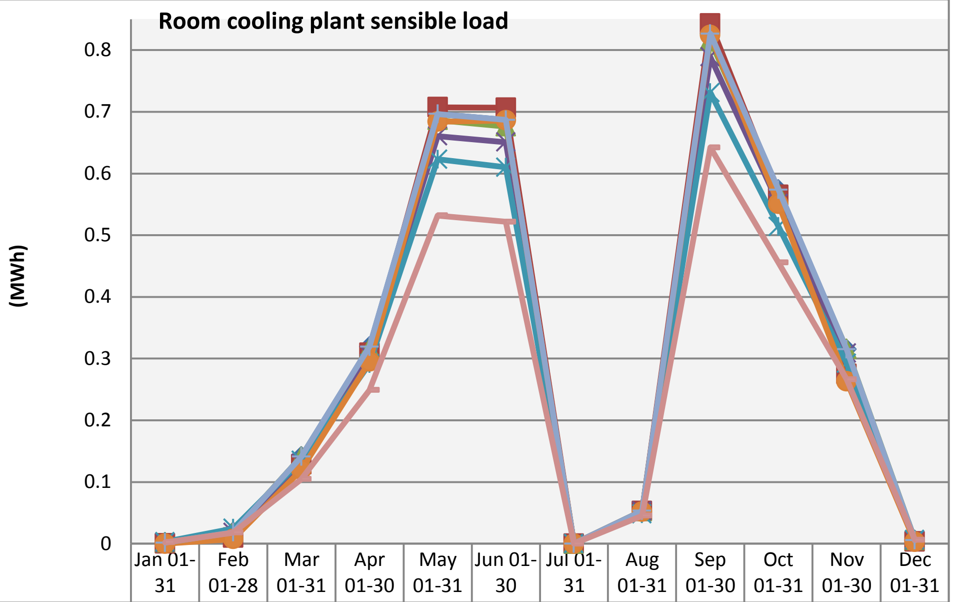
Table (5.12) showed the chart for the best scenarios nominated amongst each one of the aspects that were illustrated in detail previously. These parameters are considered the optimum of each aspect; and for that, it will be used in a combined model that will be evaluated in a new model which will be called “the optimum case” and it should be –hypothetically- the best model.

Table (5.12) Parameters and aspects of models that achieved the best performance

Parameters	Aspects	Efficient scenario
Wall aspect	Height to Depth	596WD
	Window to wall ratio	WWR 20
Building construction material U-Value	Wall U-Value	2 Pearl
	Roof U-Value	Roof DM
	Glazing U-Value	1 pearl
Window Aspect	Window HW ratio	HW 1/2
	Glazing Position	Glazing projected

5.6.1 Optimum case results

In this part of comparison, the room cooling pant sensible load is evaluated in the new optimum case and then compared with the best of each aspect models. With reference to the graph shown in figure (5.47), it shows that the optimum case has improved the amounts of saving in the classroom where it reduced remarkable cooling loads. It got the lowest value – where wall 2 Pearl gained the minimum value earlier - and achieved 13.28 % saving with regards to the least value by wall 2 pearl – which was 3.2787 MWh- and it succeeded to get 2.8433 MWh.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
Glazing Projected	0.0015	0.0184	0.1409	0.3191	0.6965	0.6869	0	0.0533	0.8265	0.5735	0.3148	0.0055
HW 1/2	0.0003	0.0098	0.1286	0.3094	0.7075	0.7066	0	0.0529	0.8431	0.5654	0.2748	0.0033
Glazing UV 1 Pearl	0.0017	0.0187	0.1407	0.316	0.6867	0.6762	0	0.053	0.8156	0.5677	0.3153	0.0057
Roof DM	0.0016	0.018	0.1304	0.3051	0.6606	0.6507	0	0.0528	0.7889	0.5511	0.3086	0.0056
Wall 2 Pearl	0.0031	0.0247	0.1347	0.2915	0.623	0.61	0	0.0479	0.7309	0.514	0.2923	0.0067
WWR 20	0	0.0074	0.1197	0.2951	0.6841	0.6862	0	0.052	0.8243	0.5505	0.2631	0.0027
596WD	0.0015	0.0184	0.1409	0.3192	0.6965	0.6869	0	0.0533	0.8265	0.5736	0.3148	0.0055
Optimum Case	0.0024	0.0178	0.1046	0.249	0.5318	0.5219	0	0.0454	0.6422	0.4555	0.2663	0.0062

Figure (5.47) Room cooling plant sensible load values
for the optimum case versus best scenarios

After assessing the total lights energy in figure (5.48), it was found that Window U-VALUE 1 Pearl is the most practical model in terms of its capacity to reduce the total annual lights energy. It reached the amount 0.0198 MWh, while 596WD, wall 2 pearl and glazing projected obtained 0.0199 MWh. uncertainly; the optimum case is much higher than expected and got 0.0238 MWh as the second highest value amongst other scenarios. That result is assumed due to the size and proportion of glazing at classroom where it doesn't help reducing annual lights consumption.

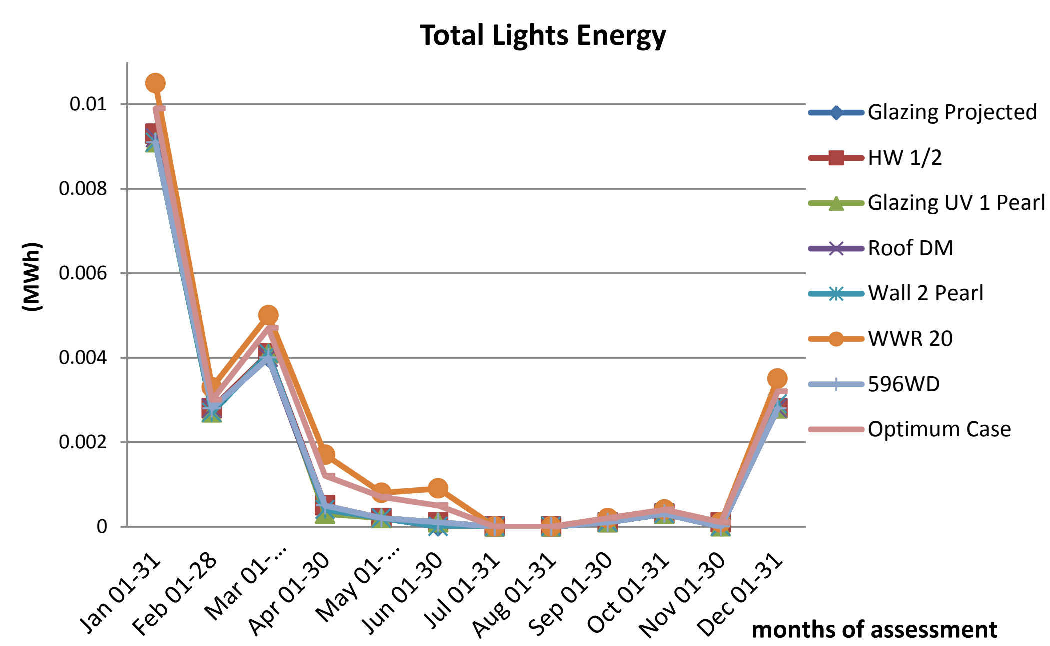
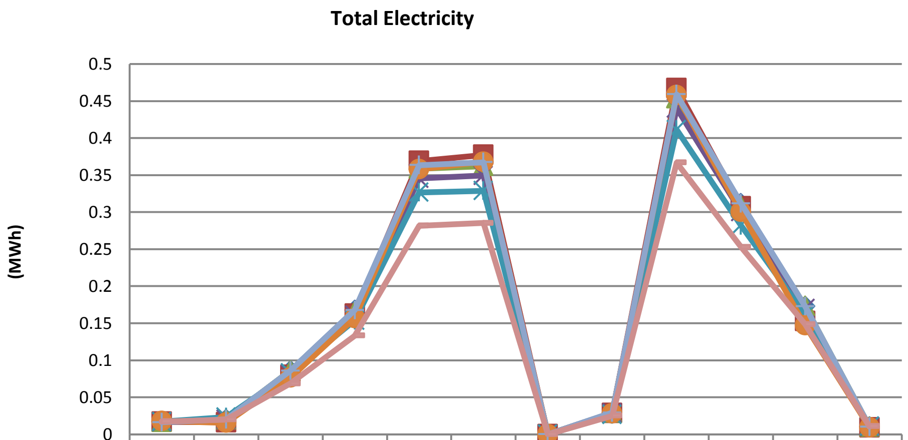


Figure (5.48) Total lights energy values for the optimum case versus best scenarios

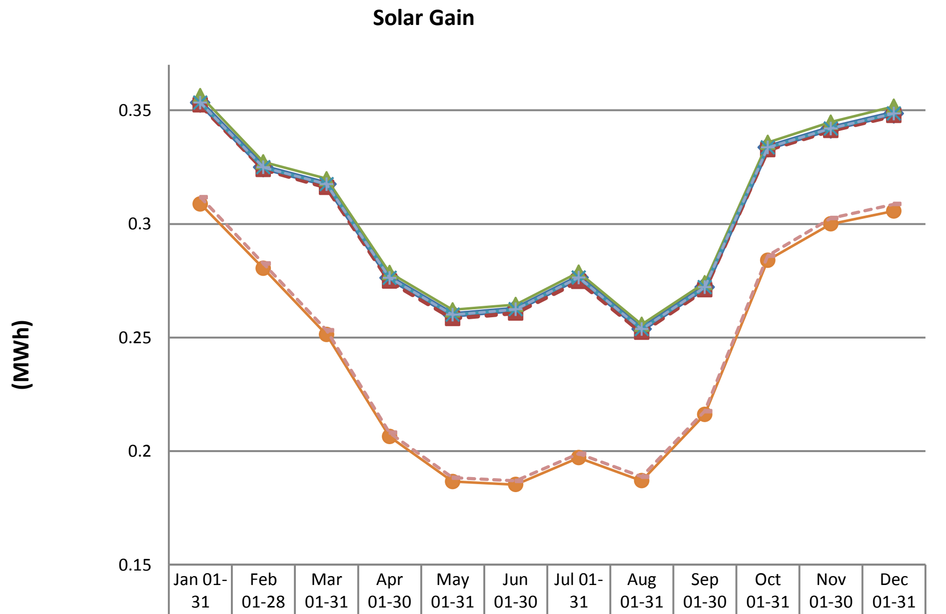
Total electricity in figure (5.49) had a brilliant result which supports the new optimum model where it achieved the lowest electrical value as low as 1.6105 MWh. The level of reduction in total electricity reached 11.72 % less than the lowest value where wall 2 pearl was the best saving aspect.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
Glazing Projected	0.0164	0.0201	0.0859	0.1676	0.3635	0.3674	0	0.0291	0.4591	0.3117	0.1729	0.0101
HW 1/2	0.0168	0.0162	0.0801	0.1628	0.369	0.3772	0	0.0288	0.4674	0.3077	0.1529	0.009
Glazing UV 1 Pearl	0.0164	0.0201	0.0859	0.166	0.3586	0.3621	0	0.0289	0.4536	0.3088	0.1731	0.0102
Roof DM	0.0164	0.0199	0.0807	0.1606	0.3455	0.3493	0	0.0288	0.4403	0.3005	0.1698	0.0101
Wall 2 Pearl	0.017	0.0231	0.0828	0.1538	0.3267	0.3289	0	0.0263	0.4113	0.2819	0.1616	0.0108
WWR 20	0.018	0.0155	0.0765	0.1569	0.3579	0.3679	0	0.0284	0.458	0.3003	0.1471	0.0094
596WD	0.0163	0.0201	0.0859	0.1677	0.3634	0.3674	0	0.0291	0.4591	0.3117	0.1729	0.0101
Optimum Case	0.0174	0.02	0.0685	0.1333	0.2816	0.2853	0	0.0251	0.367	0.2528	0.1487	0.0109

Figure (5.49) Total electricity values for the optimum case versus best scenarios

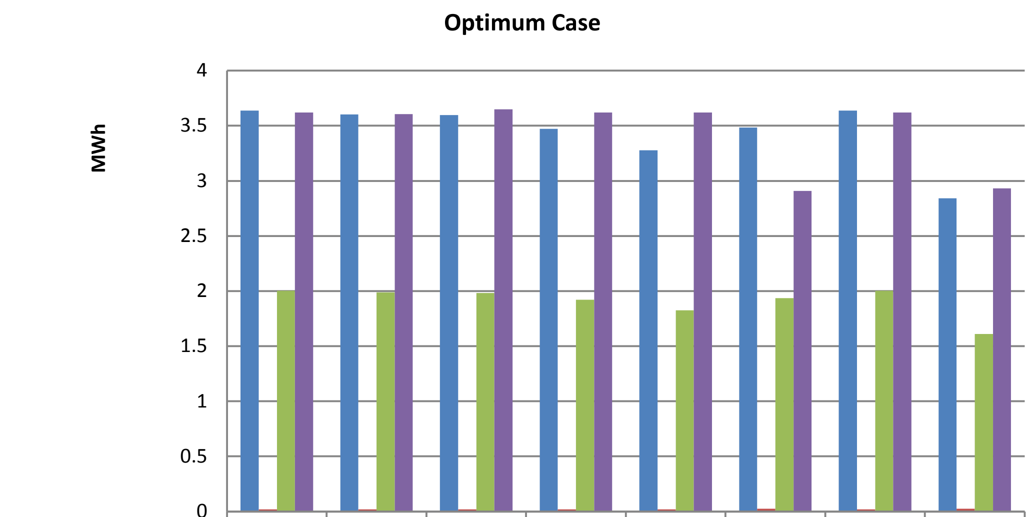
Solar gain in figure (5.50) obtained the finest cases were moderately variable but in a short range. WWR 20 achieved the best value as 2.9087 MWh, while the second was the optimum case which got 2.9331 MWh, and in this case the only variation in both of them is 0.0244 MWh. This difference is fairly acceptable to appreciate the level of saving in the optimum case.



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
Glazing Projected	0.3533	0.3249	0.3175	0.2763	0.26	0.2624	0.2764	0.2537	0.2721	0.3336	0.342	0.3486
HW 1/2	0.3523	0.324	0.3161	0.2748	0.2584	0.2608	0.2747	0.2523	0.271	0.3326	0.3411	0.3477
Glazing UV 1 Pearl	0.3564	0.3273	0.3199	0.2786	0.2622	0.2645	0.2787	0.2558	0.2741	0.3359	0.3448	0.3518
Roof DM	0.3533	0.3249	0.3175	0.2763	0.26	0.2624	0.2764	0.2537	0.2721	0.3336	0.342	0.3486
Wall 2 Pearl	0.3533	0.3249	0.3175	0.2763	0.26	0.2624	0.2764	0.2537	0.2721	0.3336	0.342	0.3486
WWR 20	0.3088	0.2804	0.2513	0.2064	0.1866	0.1853	0.1971	0.187	0.2161	0.284	0.3	0.3057
596WD	0.3533	0.3249	0.3175	0.2763	0.26	0.2624	0.2764	0.2537	0.2721	0.3336	0.342	0.3486
Optimum Case	0.3117	0.2825	0.2532	0.2081	0.1883	0.1869	0.1989	0.1887	0.2176	0.286	0.3025	0.3087

Figure (5.50) Solar gain values for the optimum case versus best scenarios

The optimum case focused on selecting the best performance of each criterion to assess if these parameters are recommended for any future renovation or construction and if it has potentials to reduce electrical loads and energy consumption in the classroom. The sum of all evaluated best models is compared with the optimum case in figure (5.51) and will explain more the level of impact on the total annual consumptions. Room cooling plant sensible load obtained from the optimum case was the best performance where it reached 2.8433 MWh. For the total lights energy outcomes, the indication of the lowest value goes to the glazing U-VALUE 1 Pearl which was 0.0198 MWh while the optimum case was the 7th out of eight models. Comparing the total electricity results, the optimum case had a great reduction of annual electricity as it achieved 1.6105 MWh, and that value is much less than the other scenarios. In the solar gain values, WWR 20 achieved the best result with 2.9087 MWh, however the optimum case obtained the second rank as it gained 2.9331 MWh.



	Glazing Projected	HW 1/2	Glazing UV 1 Pearl	Roof DM	Wall 2 Pearl	WWR 20	596WD	Optimum Case
Room cooling plant sens. load	3.637	3.6017	3.5974	3.4735	3.2787	3.4853	3.6371	2.8433
Total lights energy	0.0199	0.0204	0.0198	0.0199	0.0199	0.0263	0.0199	0.0238
Total electricity	2.0036	1.9879	1.9836	1.922	1.8243	1.9359	2.0037	1.6105
Solar gain	3.6208	3.6057	3.65	3.6208	3.6208	2.9087	3.6208	2.9331

Figure (5.51) Variables comparison the optimum case versus best scenarios

Colours shown in Table (5.13) indicate the gradient values according to the ranking of each model performance. The green presents the best performance and it's indicated as the 1st and the red mean the higher values until it reaches the 8th in the rank. Optimum case obtained 2 variables out of 4 –which were the room cooling plant sensible load and the total electricity- and it achieved the second in the solar gain.

Table (5.13) Ranking for the 8 scenarios according to the main 4 variables

1st	2nd	3rd	4th	5th	6th	7th	8th
Room cooling plant sensible load							
Optimum Case	Wall 2 Pearl	Roof DM	WWR 20	Glazing U-VALUE 1 Pearl	HW 1/2	Glazing Projected	596WD
2.8433	3.2787	3.4735	3.4853	3.5974	3.6017	3.637	3.6371
Total lights energy							
Glazing U-VALUE 1 Pearl	Roof DM	Wall 2 Pearl	596WD	Glazing Projected	HW 1/2	Optimum Case	WWR 20
0.0198	0.0199	0.0199	0.0199	0.0199	0.0204	0.0238	0.0263
Total electricity							
Optimum Case	Wall 2 Pearl	Roof DM	WWR 20	Glazing U-VALUE 1 Pearl	HW 1/2	Glazing Projected	596WD
1.6105	1.8243	1.922	1.9359	1.9836	1.9879	2.0036	2.0037
Solar Gain							
WWR 20	Optimum Case	HW 1/2	Glazing Projected	Roof DM	Wall 2 Pearl	596WD	Glazing U-VALUE 1 Pearl
2.9087	2.9331	3.6057	3.6208	3.6208	3.6208	3.6208	3.65
* All models in the table above are with dimmers * All variables shown above are the summed total in (MWh)							

The optimum case wasn't among the best values in the total lights energy as it placed the 6th, yet when looking at the variation level compared to the other scenarios, it's only a matter of 0.004 MWh margin with the best value. Consequently, the optimum case revealed its capacity to enhance the saving potentials in all variables of analysis, and according to the achieved values, this scenario can be considered as a successful sum of computerized experiments that can improving the status of the existing model performance.

5.6.2 Lighting simulation results in the optimum case

The same illuminance and sky conditions are applied also in calculating and analyzing daylighting for the optimum case room. For the artificial lights fixture, it's been fitted the same way of the 596WD grid; to compare the impact of the classroom envelopes while the light value and quantity is the same in the model.

Outcomes for flooring and working planes were summarized after conducting a simulation in FlucsPro. DF has a minimum of 0.9% while the maximum is 9.1% and the average is 4.2%. Artificial lights functioned in sometimes to recover the light needs up to the level desired. However, it reached 14% which is much less than the 596WD which obtained 17%; and this reduction is apparently due to the enhancements applied on the room aspects and configurations. The maximum artificial illuminance reached 98 lux while the minimum was 47 lux, and the average usage was 79.3 lux. In the analysis overview, the average daylight obtained 419 lux.

Table (5.14) Summery calculation for the optimum case on the working planes and flooring (IES)

Surface	Quantity	Values			Uniformity (Min./Ave.)	Diversity (Min./Max.)
		Min.	Ave.	Max.		
Working plane 1 Reflectance=0% Transmittance=100% Grid size=0.50 m Area=37.440m² Margin=0.50 m	Artificial illuminance	47.43 lux	79.30 lux	98.02 lux	0.60	0.48
	Daylight factor	0.9 %	4.2 %	9.1 %	0.23	0.10
	Daylight illuminance	82.93 lux	367.45 lux	801.27 lux	0.23	0.10
	Sky view	1.00	1.00	1.00	1.00	1.00
	Total illuminance	135.53 lux	446.75 lux	872.32 lux	0.30	0.16

When analyzing the daylighting illuminance, minimum, average and maximum were obtained as 83, 368 and 801 lux respectively as Table (5.14) has provided the analyzed data. Figure (5.52) shows the final combination between the artificial and natural daylighting penetration into the classroom in March 21st at 12:00 where the maximum reached 800 lux in that certain date, and the summed average 447 lux which was concentrated in the middle of the room and it is close to the sufficient level of 500 lux as mentioned before.

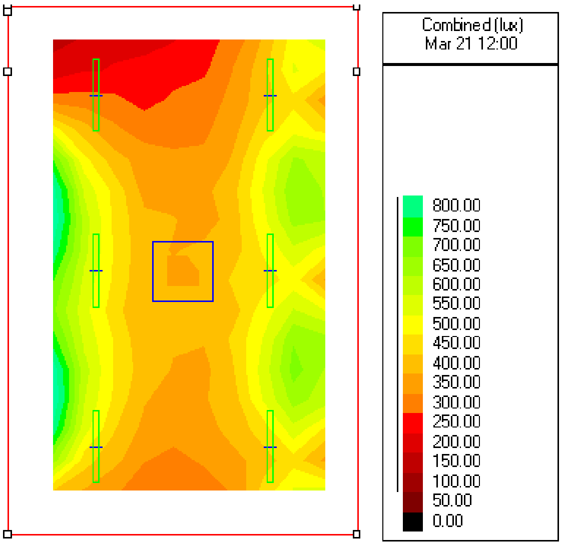


Figure (5.52) combined lux levels for optimum case in March 21 at 12:00

With the benefit of the elements provided in RadianceIES, author could analyze and cumulate many results concerning lighting in the classroom. On the working plane, total luminaire power was 276 W and the luminous efficacy reached 75 lm/W, while the uniformity in the optimum case varied between 0.6 and 0.23 out of a 1.00. The plan in figure (5.53) also shows the average luminance and the level obtained in the classroom where 475 lux was the maximum, and the average illuminance on the workspace height of 0.75m was around 250 lux on most of the middle area.

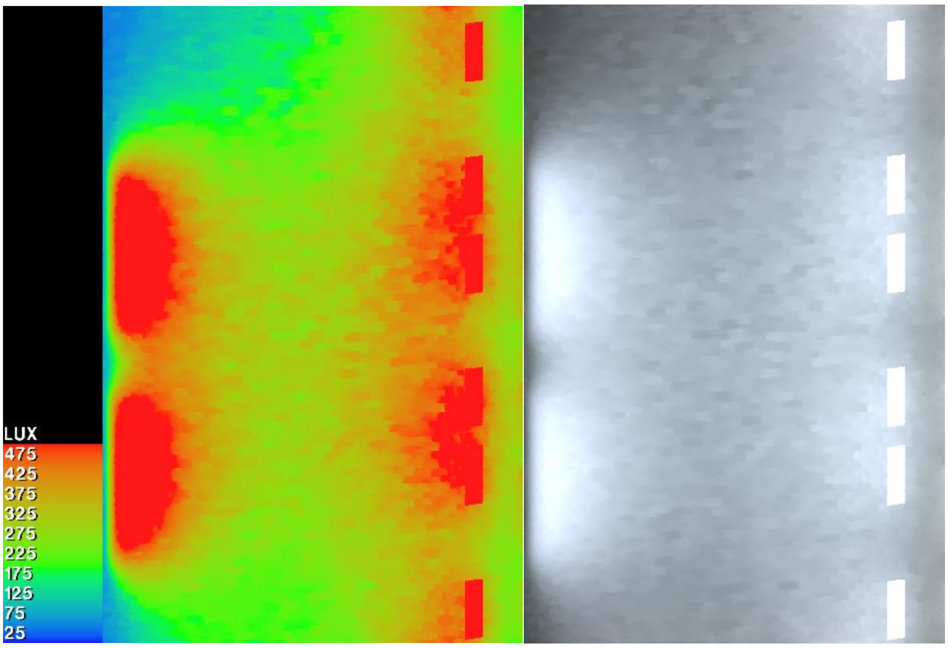


Figure (5.53) Plan showing daylighting and contour for lux levels in the optimum case

The sunny sky condition was chosen to evaluate the worst case when there is clear sky and it's too sunny in the 21st of September, and this is selected date for simulation. As shown in figure (5.54), the perspective of the optimum case with combination of the artificial lights reached the maximum of 475 lux where the uniformity and distribution of illuminance is spread across the room. It shows that the modified windows –to the right side- don't penetrate daylight because the choice of the selected orientation is the best to avoid solar radiation, and the lux contour shows considerable levels of daylighting in the optimum case that maintains the classroom with minimum total cooling and lighting annual loads.

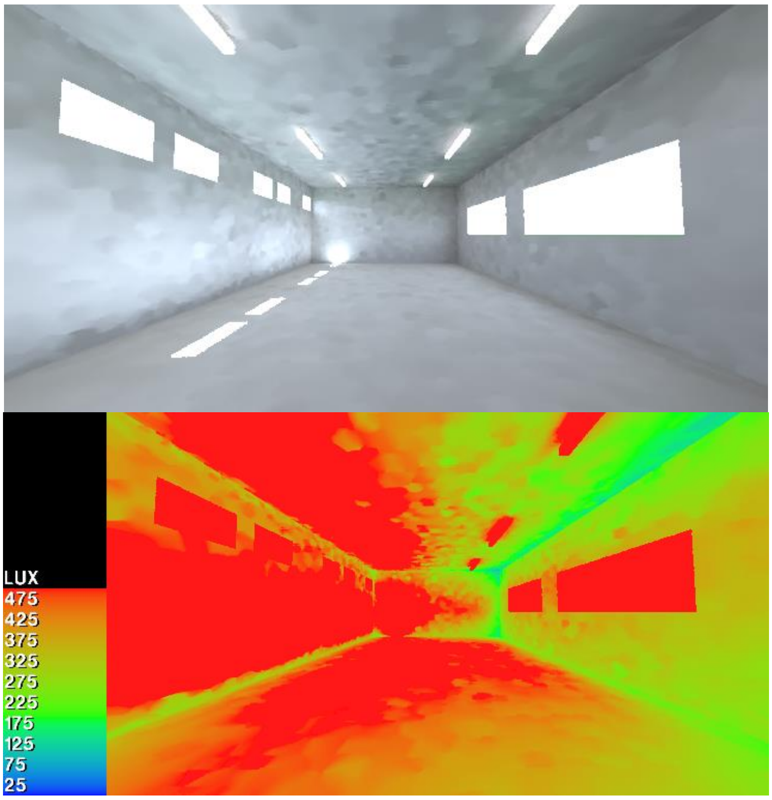


Figure (5.54) Perspective for natural and artificial light Contour levels in the optimum case

In this optimum case, some recommendations of the IES were mainly about the amount of glazing where it should be increased. The size and form of the glass has an impact on daylighting; especially when it's above 2.3 meters. Glare should be considered as well the visible transmittance aspects which should be with different types.

Chapter 6

Conclusions and Recommendations

6.1 Conclusion

Considering high performance schools refer to many factors, but most priority highlighted the daylighting and building construction materials. Schools are spreading enormously in the UAE whether governmental or private schools and all are interested to provide the best atmosphere for students and teachers to deliver their best at classrooms. When natural daylighting replaces the electric lights, it shall lead to an appropriate teaching environment and that will make a good saving of electric consumption for both lights and air conditioning –which is effected by the heat of lights along the academic day. It was beneficial to analyze researchers and academics papers and literature reviews which were concerned about delighting and energy performance; to conclude other minds experiences and utilize that knowledge in this research. After that, a section was dedicated for modeling and simulating different attempts to evaluate the existing models of classroom, and then new scenarios were offered to assess their potentialities in reducing the undesired levels of incident solar radiations and AC loads, yet maintain the level of comfort in the classroom in terms of lux level and consistent load of cooling. Eventually, a combined attempt for the best of each aspect was designed to conduct if it generates the sum of all best values, and that will be a recommended solution for future school designs that can get advantage from this investigation.

Daylighting admittance is one of the most effective factors on students' concentration and it has an impact to reduce electric lights use. Providing a sufficient and inform daylighting is valuable asset at classrooms where comfort levels are critically important requirements that should be met; due to the variable genders and ages in the end-user across the schools. The main concern in this research was to maintain a level of lighting – combined from daylighting and electrical one- to keep 500 lux in the classroom, simultaneously, to assess the possibility to reduce the cooling loads along the academic year with respect to the ideal envelope depth, height, length and glazing proportions at classroom without imposing any external device like shading elements or light shelves and skylights.

The modeling section was divided into two main parts, and then new models were based on the obtained results. The first part was based on the existing 3 models of school and their 4 possible orientations making 12 models for assessment. The second part fitted 2 sensors in the 12 cases to reduce the unrequired amounts of illumination which exceed the needed value. It was figured out that 596 West model obtained the best values in the four variables of analysis -room cooling plant sensible load, total lights energy, total electricity and solar gain. After that, new cases were built up according to critical aspects -like Estidama and DM rating system for walls, roofs, and glazing U-Values in addition to windows and walls ratios- and they were mentioned in depth in chapter five. The aim was to assess these 21 parameters and evaluate their lighting, electricity and cooling loads.

All of these aspects were compared to the best scenario of the existing cases. Ultimately, the best values obtained from each of the models were revised in 8 elements. These design elements essentially remodeled the new setting which was named as the optimum case, and it was discussed in terms of its capacity to lessen the values of cooling and lighting at the optimum classroom. Simulation outcomes showed appropriate levels of reduction of room cooling loads in the optimum case which succeeded to reduce 13.28% with respect to the second lest value and that is equivalent to 435.4 KWh. Assessment for total lights energy indicated small margin of variation where the optimum value ranked the 6^{th}, but the difference was only 4 KWh per year with reference to the lowest best result. It decreased the total electrical loads to 11.72% if compared to the second least value. Simulation attempts confirmed the capabilities of providing good amounts of daylighting and dropping electrical loads demands at classrooms and the suggested parameters enhanced the level of IEQ in connection with the obtained results in tables and charts demonstrated previously.

6.2 Recommendations

Architecture of schools buildings is motivated to integrate the design of beautiful exterior envelopes and decent interior spaces that are well-thought in the conceptual design and the development stages. The final classroom design result should influence the incident daylighting, cooling loads and that shall lead to a comfortable internal space that helps in achieving an educational performance along the day while a good HVAC system is running in a balanced level and daylighting design values without any disturbance of glare or flare. That intends to positively decrease electrical ranks and shall be cost effective factors to impact on the annual loads. In hot arid regions like the UAE should have special design solutions and these conditions can be concluded in a list of recommendations as follows:

- Designing schools should consider the building orientation and the massing scheme which can has an impact on emphasizing the incident daylighting, and it can reduce heat gains which will effect on the amounts of annual electrical loads. South direction is considerably the most important orientation where sun moves along its path the longest from that orientation. However, east and west have a substantial impact on the daylight and they have to be designed in a way to avoid the early morning and afternoon timing. North direction has a great daylighting quality which produces the least solar gain, and shading is not needed due to the timing of study which commences at 07:00 am.

- Preparing classrooms according to the needed daily profiles of attendee can be advantageous in reducing the extra amounts of cooling loads. Placing sensors on the work space level will create an automated lighting control where this daylighting dimmer can save great lighting loads; especially that this research was conducted in the UAE which has the majority of its days as a clear sky condition and would be a privilege to deduct the annual loads of both lights and cooling loads.

- As the daylighting penetration increases in any space, the efficiency of dimming control logic can decrease linearly good lighting loads, and consequently will lessen the total load of the building. It's important here to install sensors in the classroom at certain studied distance away from the window to operate them for prime results.

- Wall aspects as the window to wall ratio WWR and the height to depth ratio have great impact on the daylighting at a certain classroom, but the depth be with within the range of 6 meters. According to the conducted simulation, the best value was in the 1/2 HtoD ratio. WWR is a parameter which has a critical impact on energy performance and it should be calculated with respect to the building envelope. In the best case of this research, the WWR 20 obtained the least consumption values between the other scenarios. These variable should be assessed in an integrated design to evaluate its positive and negative impact on building performance for both daylighting and energy consumption.

- It's definite that building construction materials have excessive impact on the annual energy performance loads. Municipalities are making a great effort to establish a firm base for green rules–as illustrated for DM and Estidama rating codes- which help in reducing the impacts of harmful emitting materials and pushing towards better ingredients and products. Low U-Value materials are recommended and the more studied layering systems for walls, roofs and windows the better results can be achieved in the final electric loads. Insulation is a powerful factor that leads to improving the control of heat gain or loss. Combining all of these elements incorporates a good strategy to reduce the undesired amounts of lights and cooling loads.

- Windows have been illustrated in depth and they showed a significant reduction impact on the classrooms. Opening should be decided according to the needed level of comfort, and height to width ratio has guidelines to support in designing a proper glazing ratio for the classroom. Increasing this ratio will heat up the space to undesired levels and most probably will create glare and disturb the users. H/W ratio was the best as 1/2 in the modeled classroom. For such study, using the virtual computerization helps in evaluating all desired ratios to judge which of them can be the most suitable case.

Glazing position also can be productive in case of having a deep classroom envelope. Reallocating the glazing from the middle to be internally or externally flush have different results in solar gain, internal shading and it can reduce glare levels at the space.

- In the process of developing the optimum case, it was found that the possibility to collect the best of each parameter can be collaborative and useful to build up a new case which reduces consumption amounts. And with reference to such benchmark, it can be used to upgrade the base case to have a better performance that effect positively in the environmental solutions, and concurrently it will ensure the objectives and goals of the research which was concerned about providing the best uniform sufficient daylighting with a great energy performance.

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APPENDICES

APPENDIX A.

Comparison between classrooms with dimmers and the best case daylighting result

Table (A.1) Variables comparison between classrooms with dimmers (Author)

1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Room cooling plant sensible load											
596 West	596 North	596 East	586 West	596 South	586 North	586 East	586 South	KAT South	KAT North	KAT West	KAT East
3.6371	3.9545	4.0564	4.0686	4.1797	4.3899	4.4374	4.5499	4.7236	4.7497	5.0345	5.058
Total lights energy											
596 South	586 South	596 East	KAT North	596 North	596 West	586 West	KAT East	KAT West	KAT South	586 North	586 East
0.0109	0.0113	0.012	0.0174	0.0182	0.0199	0.0214	0.0267	0.0404	0.0434	0.0491	0.1288
Total electricity											
596 West	596 East	596 North	586 West	596 South	586 North	586 South	586 East	KAT North	KAT South	KAT East	KAT West
2.0037	2.2046	2.1609	2.2251	2.2663	2.4135	2.456	2.5156	2.5853	2.5981	2.7496	2.7514
Solar Gain											
596 West	586 West	596 East	596 South	596 North	KAT South	KAT North	586 East	586 South	586 North	KAT West	KAT East
3.6208	4.2019	5.4134	5.8698	5.9775	6.0156	6.06	6.1418	6.6436	6.7561	7.8076	7.817

* All models in the table above are with dimmers

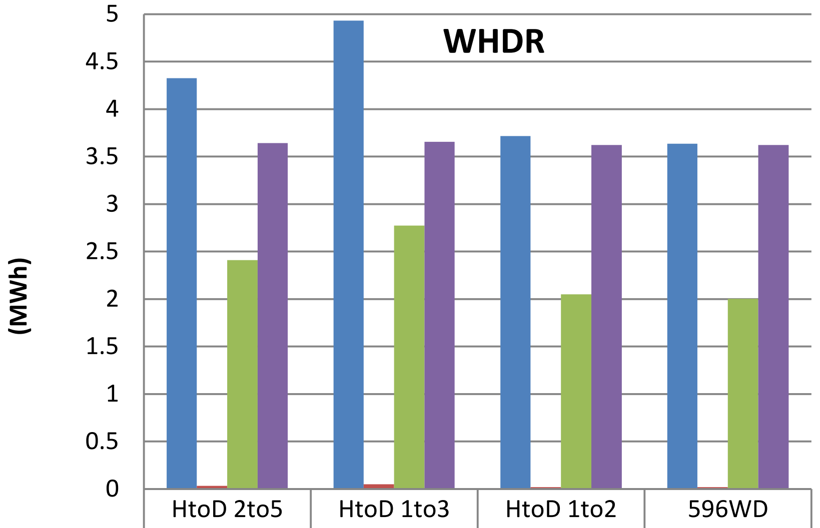
* All variables shown above were the summed totals in (MWh)

Table (A.2) Summery calculation for 596WD on the working planes and flooring (IES)

Surface	Quantity	Values			Uniformity (Min./Ave.)	Diversity (Min./Max.)
		Min.	Ave.	Max.		
Working plane 1 Reflectance=0% Transmittance=100% Grid size=0.50 m Area=37.440m² Margin=0.50 m	Artificial illuminance	0.00 lux	0.00 lux	0.00 lux	0.00	0.00
	Daylight factor	2.6 %	5.8 %	12.3 %	0.44	0.21
	Daylight illuminance	224.54 lux	512.89 lux	1085.07 lux	0.44	0.21
	Sky view	1.00	1.00	1.00	1.00	1.00
	Total illuminance	224.54 lux	512.89 lux	1085.07 lux	0.44	0.21

APPENDIX B.

New scenarios results for wall aspects



	HtoD 2to5	HtoD 1to3	HtoD 1to2	596WD
Room cooling plant sens. load	4.3254	4.9334	3.7177	3.6371
Total lights energy	0.0343	0.0499	0.021	0.0199
Total electricity	2.4112	2.7742	2.0508	2.0037
Solar gain	3.6419	3.6552	3.6237	3.6208

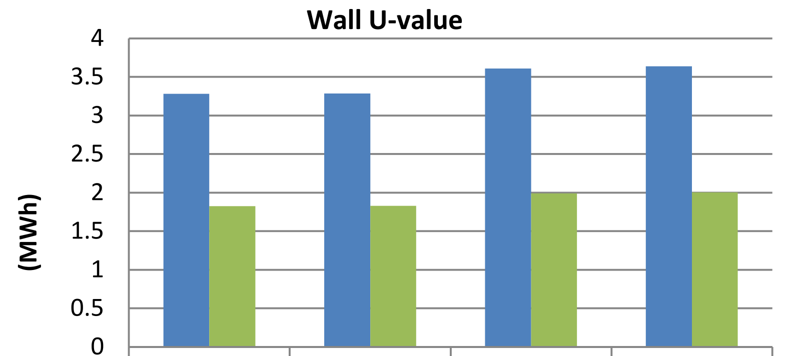
Figure (B.1) Total variables comparison between scenarios in WHDR

	WWR 40	WWR 30	WWR 20	596WD
Room cooling plant sens. load	3.6682	3.5771	3.4853	3.6371
Total lights energy	0.0191	0.0204	0.0263	0.0199
Total electricity	2.0198	1.9757	1.9359	2.0037
Solar gain	3.9982	3.4615	2.9087	3.6208

Figure (B.2) Total variables comparison between scenarios in WWR

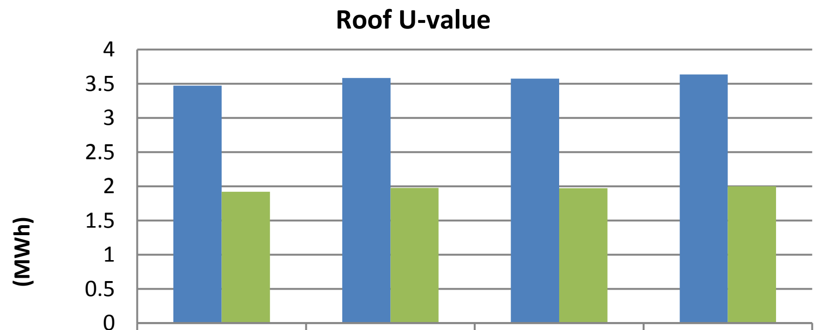
APPENDIX C.

New scenarios results for building construction materials U-values



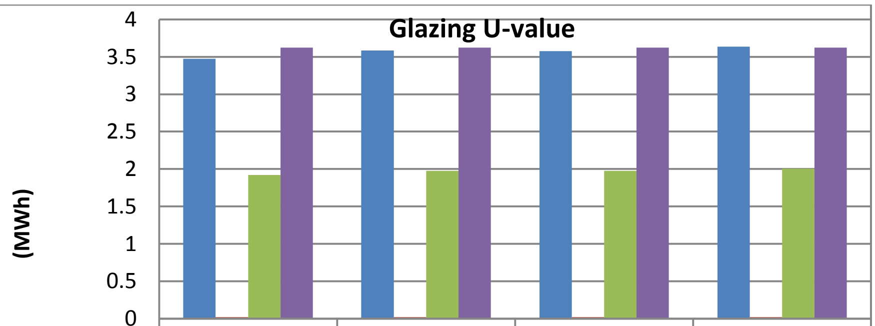
	Wall 2 Pearl	Wall 1 Pearl	Wall DM	596WD
Room cooling plant sens. load	3.2787	3.2856	3.609	3.6371
Total electricity	1.8243	1.8277	1.9896	2.0037

Figure (C.1) Total variables comparison between scenarios in Wall U-Value



	Roof DM	Roof 1 Pearl	Roof 2 Pearl	596WD
Room cooling plant sens. load	3.4735	3.5851	3.577	3.6371
Total electricity	1.922	1.9776	1.9737	2.0037

Figure (C.2) Total variables comparison between scenarios in roof U-Value

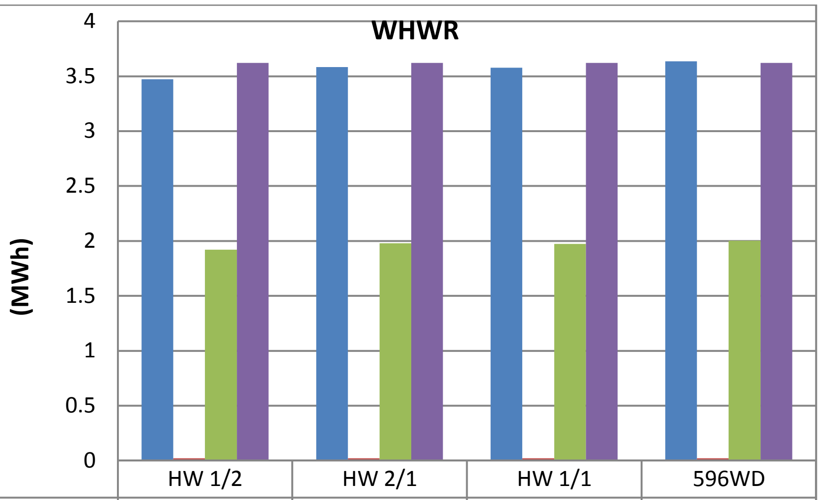


	Window UV 1 Pearl	Window UV 2 Pearl	Window UV DM	596WD
Room cooling plant sensible load	3.4735	3.5851	3.577	3.6371
Total lights energy	0.0199	0.0198	0.02	0.0199
Total electricity	1.922	1.9776	1.9737	2.0037
Solar gain	3.6208	3.6208	3.6208	3.6208

Figure (C.3) Total variables comparison between scenarios in glazing U-Value

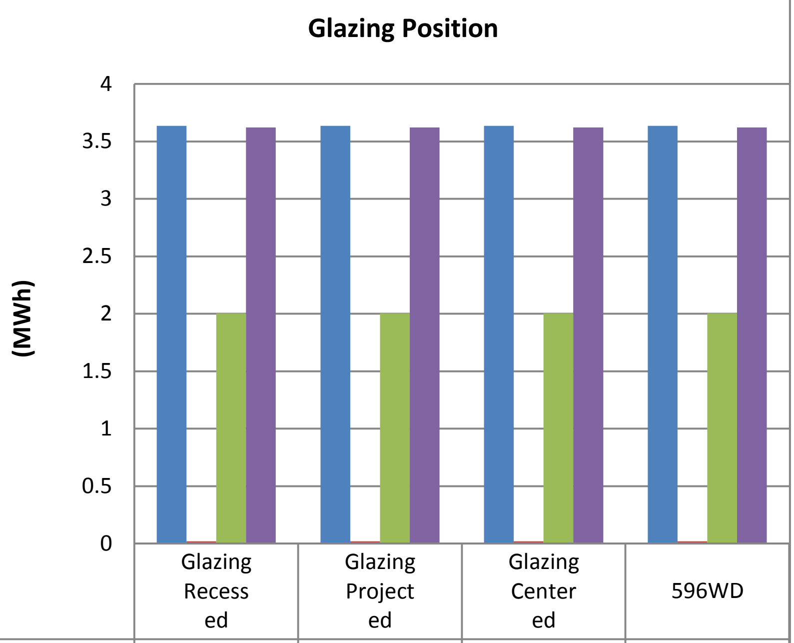
APPENDIX D.

New scenarios results for windows aspects



	HW 1/2	HW 2/1	HW 1/1	596WD
Room cooling plant sensible load	3.4735	3.5851	3.577	3.6371
Total lights energy	0.0199	0.0198	0.02	0.0199
Total electricity	1.922	1.9776	1.9737	2.0037
Solar gain	3.6208	3.6208	3.6208	3.6208

Figure (D.1) Total variables comparison between scenarios in WHWR ratio

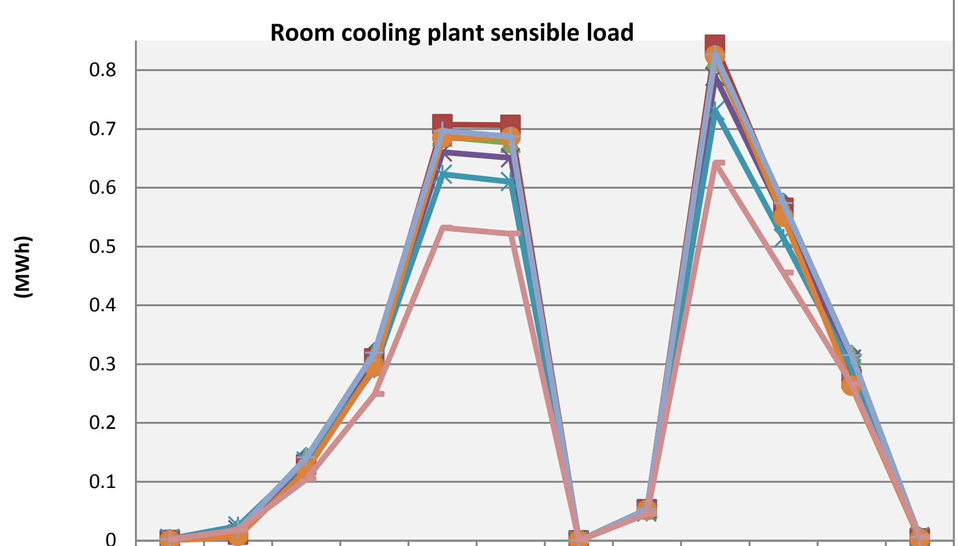


	Glazing Recessed	Glazing Projected	Glazing Centered	596WD
Room cooling plant sens. load	3.6371	3.637	3.6371	3.6371
Total lights energy	0.0199	0.0199	0.0199	0.0199
Total electricity	2.0036	2.0036	2.0037	2.0037
Solar gain	3.6208	3.6208	3.6208	3.6208

Figure (D.2) Total variables comparison between scenarios in glazing position

APPENDIX E.

Optimum case simulation results and it's comparison with the best case of each aspect



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
Glazing Projected	0.0015	0.0184	0.1409	0.3191	0.6965	0.6869	0	0.0533	0.8265	0.5735	0.3148	0.0055
HW 1/2	0.0003	0.0098	0.1286	0.3094	0.7075	0.7066	0	0.0529	0.8431	0.5654	0.2748	0.0033
Glazing UV 1 Pearl	0.0017	0.0187	0.1407	0.316	0.6867	0.6762	0	0.053	0.8156	0.5677	0.3153	0.0057
Roof DM	0.0016	0.018	0.1304	0.3051	0.6606	0.6507	0	0.0528	0.7889	0.5511	0.3086	0.0056
Wall 2 Pearl	0.0031	0.0247	0.1347	0.2915	0.623	0.61	0	0.0479	0.7309	0.514	0.2923	0.0067
WWR 20	0	0.0074	0.1197	0.2951	0.6841	0.6862	0	0.052	0.8243	0.5505	0.2631	0.0027
596WD	0.0015	0.0184	0.1409	0.3192	0.6965	0.6869	0	0.0533	0.8265	0.5736	0.3148	0.0055
Optimum Case	0.0024	0.0178	0.1046	0.249	0.5318	0.5219	0	0.0454	0.6422	0.4555	0.2663	0.0062

Figure (E.1) Room cooling plant sensible load values for the optimum case versus best scenarios

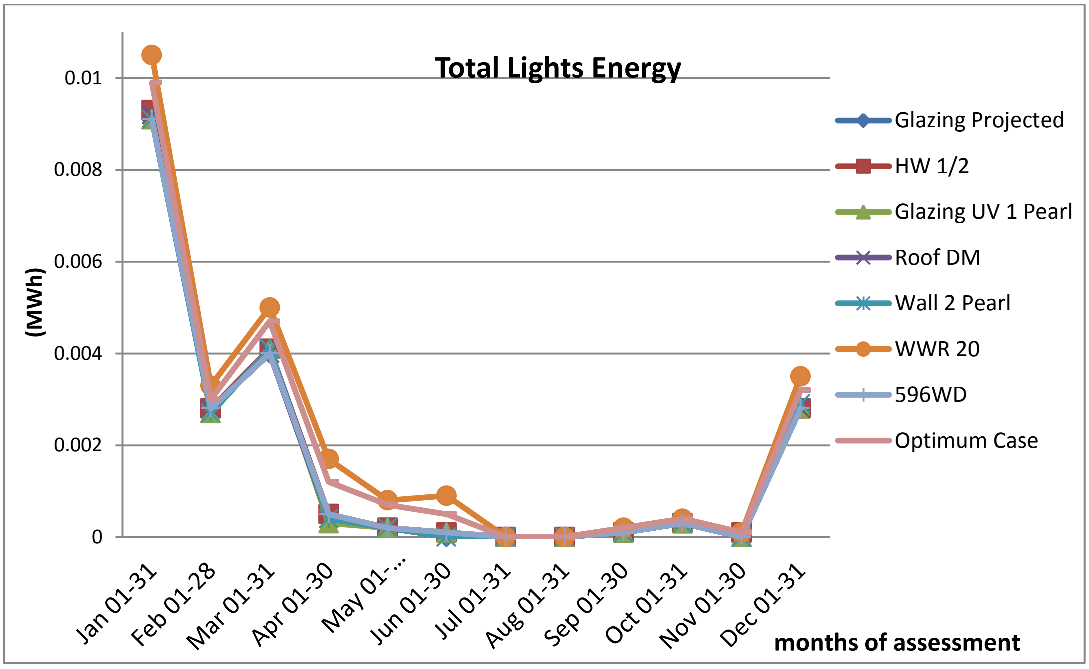
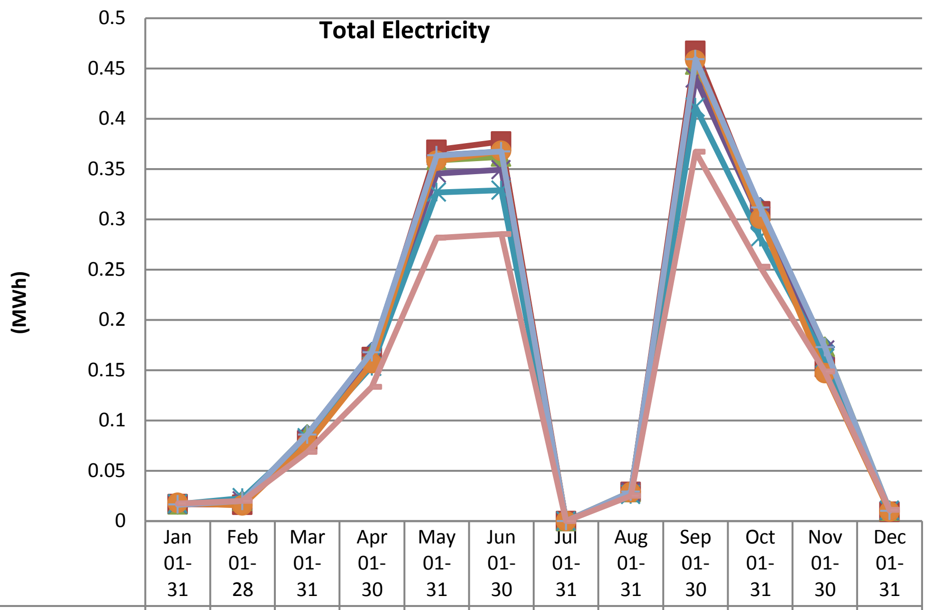
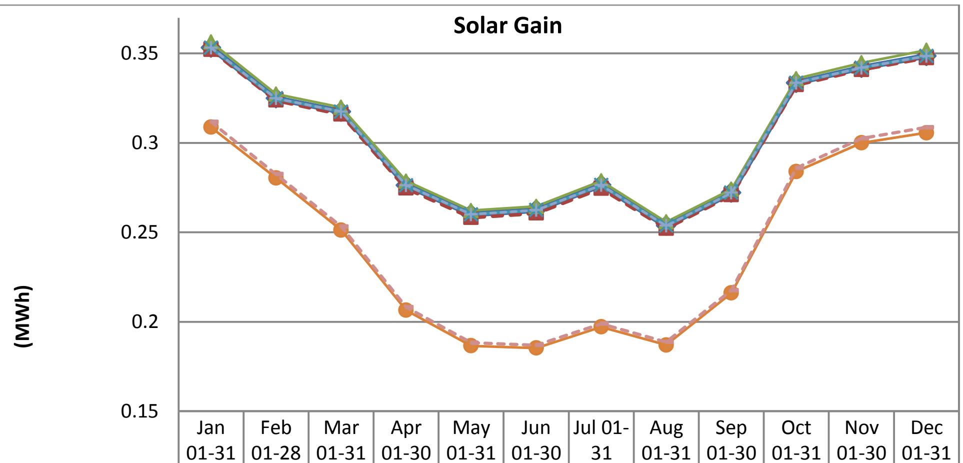


Figure (E.2) Total lights energy values for the optimum case versus best scenarios



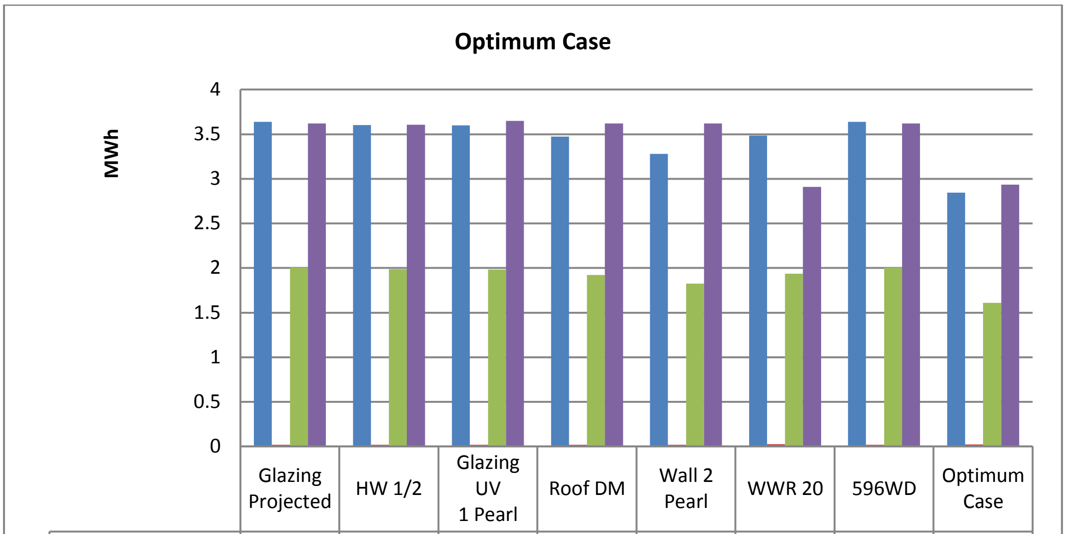
	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
Glazing Projected	0.016	0.02	0.086	0.168	0.364	0.367	0	0.029	0.459	0.312	0.173	0.01
HW 1/2	0.017	0.016	0.08	0.163	0.369	0.377	0	0.029	0.467	0.308	0.153	0.009
Glazing UV 1 Pearl	0.016	0.02	0.086	0.166	0.359	0.362	0	0.029	0.454	0.309	0.173	0.01
Roof DM	0.016	0.02	0.081	0.161	0.346	0.349	0	0.029	0.44	0.301	0.17	0.01
Wall 2 Pearl	0.017	0.023	0.083	0.154	0.327	0.329	0	0.026	0.411	0.282	0.162	0.011
WWR 20	0.018	0.016	0.077	0.157	0.358	0.368	0	0.028	0.458	0.3	0.147	0.009
596WD	0.016	0.02	0.086	0.168	0.363	0.367	0	0.029	0.459	0.312	0.173	0.01
Optimum Case	0.017	0.02	0.069	0.133	0.282	0.285	0	0.025	0.367	0.253	0.149	0.011

Figure (E.3) Total electricity values for the optimum case versus best scenarios



	Jan 01-31	Feb 01-28	Mar 01-31	Apr 01-30	May 01-31	Jun 01-30	Jul 01-31	Aug 01-31	Sep 01-30	Oct 01-31	Nov 01-30	Dec 01-31
Glazing Projected	0.3533	0.3249	0.3175	0.2763	0.26	0.2624	0.2764	0.2537	0.2721	0.3336	0.342	0.3486
HW 1/2	0.3523	0.324	0.3161	0.2748	0.2584	0.2608	0.2747	0.2523	0.271	0.3326	0.3411	0.3477
Glazing UV 1 Pearl	0.3564	0.3273	0.3199	0.2786	0.2622	0.2645	0.2787	0.2558	0.2741	0.3359	0.3448	0.3518
Roof DM	0.3533	0.3249	0.3175	0.2763	0.26	0.2624	0.2764	0.2537	0.2721	0.3336	0.342	0.3486
Wall 2 Pearl	0.3533	0.3249	0.3175	0.2763	0.26	0.2624	0.2764	0.2537	0.2721	0.3336	0.342	0.3486
WWR 20	0.3088	0.2804	0.2513	0.2064	0.1866	0.1853	0.1971	0.187	0.2161	0.284	0.3	0.3057
596WD	0.3533	0.3249	0.3175	0.2763	0.26	0.2624	0.2764	0.2537	0.2721	0.3336	0.342	0.3486
Optimum Case	0.3117	0.2825	0.2532	0.2081	0.1883	0.1869	0.1989	0.1887	0.2176	0.286	0.3025	0.3087

Figure (E.4) Solar gain values for the optimum case versus best scenarios



	Glazing Projected	HW 1/2	Glazing UV 1 Pearl	Roof DM	Wall 2 Pearl	WWR 20	596WD	Optimum Case
Room cooling plant sens. load	3.637	3.6017	3.5974	3.4735	3.2787	3.4853	3.6371	2.8433
Total lights energy	0.0199	0.0204	0.0198	0.0199	0.0199	0.0263	0.0199	0.0238
Total electricity	2.0036	1.9879	1.9836	1.922	1.8243	1.9359	2.0037	1.6105
Solar gain	3.6208	3.6057	3.65	3.6208	3.6208	2.9087	3.6208	2.9331

Figure (E.5) Variables comparison the optimum case versus best scenarios

Table (E.1) Ranking for the 8 scenarios according to the main 4 variables

1st	2nd	3rd	4th	5th	6th	7th	8th
Room cooling plant sensible load							
Optimum Case	Wall 2 Pearl	Roof DM	WWR 20	Glazing U-VALUE 1 Pearl	HW 1/2	Glazing Projected	596WD
2.8433	3.2787	3.4735	3.4853	3.5974	3.6017	3.637	3.6371
Total lights energy							
Glazing U-VALUE 1 Pearl	Roof DM	Wall 2 Pearl	596WD	Glazing Projected	HW 1/2	Optimum Case	WWR 20
0.0198	0.0199	0.0199	0.0199	0.0199	0.0204	0.0238	0.0263
Total electricity							
Optimum Case	Wall 2 Pearl	Roof DM	WWR 20	Glazing U-VALUE 1 Pearl	HW 1/2	Glazing Projected	596WD
1.6105	1.8243	1.922	1.9359	1.9836	1.9879	2.0036	2.0037
Solar Gain							
WWR 20	Optimum Case	HW 1/2	Glazing Projected	Roof DM	Wall 2 Pearl	596WD	Glazing U-VALUE 1 Pearl
2.9087	2.9331	3.6057	3.6208	3.6208	3.6208	3.6208	3.65

* All models in the table above are with dimmers
* All variables shown above are the summed total in (MWh)